

AN
ESSAY
ON THE CONSTRUCTION OF
WHEEL-CARRIAGES,
AS THEY AFFECT BOTH
ROADS AND HORSES;
WITH SUGGESTIONS RELATING TO
TOLLS
AND THE
FORMATION OF ROADS.

86 B. 700
0

Herbert Jan

Major late 12 R. Lancers

1880 Member of C. Club

Bought in Hannover 5/-



JOHN A. SEAVERNS



AN
ESSAY
ON THE CONSTRUCTION OF
WHEEL-CARRIAGES,
AS THEY AFFECT BOTH
THE ROADS AND THE HORSES;
WITH
SUGGESTIONS
RELATING TO THE PRINCIPLES ON WHICH
TOLLS
OUGHT TO BE IMPOSED,
AND
A FEW REMARKS ON THE
FORMATION OF ROADS.

BY
JOSEPH STORRS FRY.

London:

PRINTED FOR

J. AND A. ARCH, CORNHILL; BALDWIN AND CO. PATERNOSTER-
ROW, AND HARDING, ST. JAMES'S STREET;
AND T. J. MANCHEE, BRISTOL.

1820.

Printed by T. J. Manchee, Bristol.

TO THE
MARQUIS OF LANSDOWN,
PRESIDENT;

TO THE
VICE-PRESIDENTS
AND
MEMBERS
OF THE
Bath and West of England
AGRICULTURAL SOCIETY;

THIS
ESSAY
ON
AN IMPORTANT BRANCH OF
RURAL ŒCONOMY,
IS RESPECTFULLY INSCRIBED
BY
THE AUTHOR.



THE greatest part of the following Essay was written in the winter 1798 - 9. Since which time several valuable communications have been made to the Public, on the subject of Wheel-Carriages. Still, however, the Author of these pages conceives that there are some important considerations, connected with this subject, that have never been noticed by any other writer; otherwise his manuscript would have remained on the shelf. But considering that it is a duty we owe to Society, to endeavour to add to the stock of useful information, he has presumed to submit his thoughts to the Public; and he hopes they will meet with candid and impartial investigation from those by whom they may be perused.

The Author deems it proper to add that, as it is his wish to render this work an object of interest to persons not conversant with such subjects, he has studiously avoided technical phrases, as well as those that are not in frequent use ; but, when such necessarily occur, they are generally accompanied with an explanation : on this account, his style may be censured as too familiar ; a charge he very willingly risks, for the sake of obtaining what ought to be the great object of every Writer, that of being understood by his Readers ; and how far he has succeeded they will judge.

Frenchay, near Bristol,
6th Month 21, 1820.

CONTENTS.

CHAPTER I.

1. On the Mechanical Use of Wheels, in lessening Friction.—2. Polished Axles in Oil cause very little resistance to the Horses.—3. Objects which are the principal Causes of Resistance to the labour of the Horses.—4. Axle-friction, in some cases very great.—5. Wheels act as Levers in surmounting obstacles; demonstrated.—6. High Wheels advantageous, only to a certain extent.—7. Table of Powers equal to the Resistance of Wheels, when opposed to certain objects.—8. Power is actually exerted in surmounting an obstacle, as set down in the Table, notwithstanding the velocity or momentum that any Carriage may have acquired.

CHAPTER II.

1. Conical Wheels injurious, both to Roads and Horses.—2. Conical Wheels wear out faster than Cylindrical ones.—3. Cylindrical Wheels and Axles best. Subject to only three-fourths the usual Toll.—4. High Wheels not disadvantageous going up hill.—5. Broad-Wheel Waggons extremely injurious to the Roads. Projecting-heads of Tire-Nails.—6. Broad-Wheel Waggons not so advantageous to the Public Carrier as lighter Carriages.

CHAPTER III.

1. Modern Stage-Coaches; unphilosophical. Supposed origin of the custom of persons riding on the tops of them.—2. Regulations for the security of Passengers suggested.—3. All Passengers by Public Carriages might be, and ought to be, protected from the weather.—4. Objections answered. Traces of Horses drawing, ought to be placed horizontally. By the present construction of Coaches, Horses have to draw the same load, over the same obstruction, twice.—5. Centre of gravity of these Coaches simply illustrated.

CHAPTER IV.

1. A new principle suggested, as important in the Construction of Carriages, viz. the DIVISION OF WEIGHT, or POWER, by the use of a greater number of Wheels for the same load; thus causing less labour to the Horses and less injury to the Roads.—2. Carriages should press the road with the least possible weight on any one wheel. Less labour required to draw several wheels in succession, over an obstruction, than to draw one wheel, carrying the same amount of weight, over the same object.—3, 4, 5. Illustration of this Theory.—6. Breadth of wheels no security against the destructive effects of pressure. Broad Wheels on paving-stones.—7. The principle of light pressure should be carried as far as may be consistent with public convenience.—8. Light Waggon for one horse suggested.—9. Six-wheel and Eight-wheel Carriages recommended. Were in use some years ago. Were remarkably easy to travellers.—10. Had one defect in construction.—11. Carried enormous loads with four horses.

CHAPTER V.

1. Friction does not increase with the increase of the rubbing-surfaces: proved; consequently not with an in-

crease of the number of axles. Practice of the Author.—2. Practical use of many wheels.—3. Proposed remedy for the old defect in the construction of Six-wheel and Eight-wheel Carriages, illustrated by engravings.—4. Causes why the Six-wheel and Eight-wheel Coaches were discontinued.—5. Suggestions for obviating these causes.—6. Matthews's Patent Coach.

CHAPTER VI.

1. Comparative effect on the Horses, by the use of Carriages of Two wheels, of Four wheels, of Six wheels, and of Eight wheels, all carrying the same gross weight. Illustrated by a Table.—2. Fore-wheels the pioneers of the hinder-wheels.—3. The roads *doubly* interested in the question of heavy or light pressure.

CHAPTER VII.

1. Tolls should be imposed on Wheels only, without regard to the number of horses drawing any carriage.—2. A liberal number of horses, to any carriage, advantageous to the Road.—3. Eight-Wheel Carriages, to weigh forty-eight hundred-weight gross, ought to be encouraged by low tolls, as most advantageous to the Proprietors, and to the Roads. 4. If intensity of pressure on each wheel be removed, the form or width of the wheel is of little consequence.—5. Cylindrical wheels preferable, even for the lightest weights.

CHAPTER VIII.

1. Principle on which Tolls ought to be imposed.—2. How a Table of Tolls ought to be calculated, to meet this principle.—3. A Table of Tolls, calculated on this principle.—4. Operation of Tolls so calculated. Opinion of JOHN LOUDON M^cADAM.—5. Opinion of the Legislature, in 13th Geo. III. on the injury caused by excessive weights. Sixteen-

inch rollers, as now constructed, liable to an additional toll of *Forty Pounds*.—6. Breadth of Wheels no security against the destructive effects of pressure, further shown.—7. Probable reasons why Heavy Waggons were formerly encouraged.—8. Wheels of light pressure more urgently necessary, where the materials for roads are of a soft and bad quality.

CHAPTER IX.

1. Springs, their use explained. How they operate to the ease of the Rider.—RICHARD LOVELL EDGEWORTH's Experiments on Springs.

CHAPTER X.

1. Suggestions respecting the 'Tax on Stage-Coaches.—
2. Private Carriages. Taxed Carts.

CHAPTER XI.

1. Mechanical Action of Wheels on the Materials of Roads explained.—2. Narrow Roads, why so frequently in bad condition. Deep ditches and sudden falls of the ground, close to the sides of roads, productive of ruts.—3. Convex Roads never wear well, and why.—4. Materials for Roads. Laying on of Materials.—5. Whether a thick or a thin covering at one time.—6. Whether the whole breadth of a road, or only half of it, should be covered at one time.

APPENDIX.

Remarks on the Friction of Axles, the Elasticity of the Subsoils, and the Softness of the Surface-matter of Roads, as relating to the principle of Division of Weight.—On Fat and Oils of different kinds, as applicable to the Axles of Wheels, and to other Machinery.

ESSAY,

&c.

CHAPTER I.

1. *On the Mechanical Use of Wheels, in lessening Friction.*—2. *Polished Axles in Oil cause very little resistance to the Horses.*—3. *Objects which are the principal Causes of Resistance to the labour of the Horses.*—4. *Axle-friction, in some cases, very great.*—5. *Wheels act as Levers in surmounting obstacles; demonstrated.*—6. *High Wheels advantageous, only to a certain extent.*—7. *Table of Powers equal to the Resistance of Wheels, when opposed to certain objects.*—8. *Power is actually exerted in surmounting an obstacle, as set down in the Table, notwithstanding the velocity or momentum that any Carriage may have acquired.*

1. **THE** use of wheels, in lessening friction, is well defined, in an Essay published in the year 1790, by my friend ROBERT ANSTICE, of Bridgewater. He says, “A Carriage,

such as a sledge, sliding over a plane (or road), suffers a friction, or rubbing of its parts against the plane, equal to the distance through which it moves; but, if an axle be applied to it, whose circumference shall be six inches, and on that wheels be placed, whose circumference shall be eighteen feet, it is evident that, in moving the carriage eighteen feet over the plane, the wheels will make but one revolution; and as there is no sliding of parts between the plane and the wheels, but a mere change of surface, by one part of the latter rising, and the other descending, nearly perpendicular to the former, no friction will take place there; the whole being transferred to the nave acting on the axle; which nave, having made but the same one revolution as the outer circumference of the wheel, there has been but a sliding of parts equal to the circumference of the hole in the nave; which, if it fitted the axle, would be but six inches. Consequently, the friction is lessened as one to thirty-six, besides the advantage gained

of confining it to so small a surface, whereby the parts are more easily kept smooth, and fitted to each other; and substances (oil or grease) applied and retained to lessen the remaining friction."—Indeed the difference between drawing a sledge eighteen feet, or even fifteen feet, upon a rough road, and drawing the same weight supported by polished steel, sliding upon polished brass, with olive-oil between them, six or even nine inches, is astonishingly great.

2. In the latter case, the friction is so wonderfully reduced as to be scarcely an object of consideration. In what degree it is reduced it would be difficult to determine, even by experiment; as the friction of sledges varies on every variety of road: it is also different in wet weather and in dry. I do not, however, think that more than one hundredth part of the labour of the horses is expended, in overcoming the friction of these polished oiled metals one against another. I insist the more on this point, as it is im-

portant to know what causes the resistance which our horses have to overcome, and because I think that the friction of the axles is very much over-rated. That it is very highly rated is evident, by the wonderful effects that are announced, as produced by such and such Patent Boxes; as though the labour of the horses were to be reduced in a very considerable degree by the use of them. Those axles and boxes are undoubtedly the best, of which the axles are polished steel, and perfectly cylindrical; and the boxes, brass, neatly bored, and all well fitted together, with the least *shoulder-friction*; and furnished with a reservoir for oil.

3. The other ninety-nine hundredths of the power are applied in overcoming all the objects which cause resistance under ordinary circumstances; which would not exist, if the outward edges of the wheels were of steel, accurately turned in lathes; and if the carriages moved on surfaces of polished steel, perfectly horizontal; and if all resistance

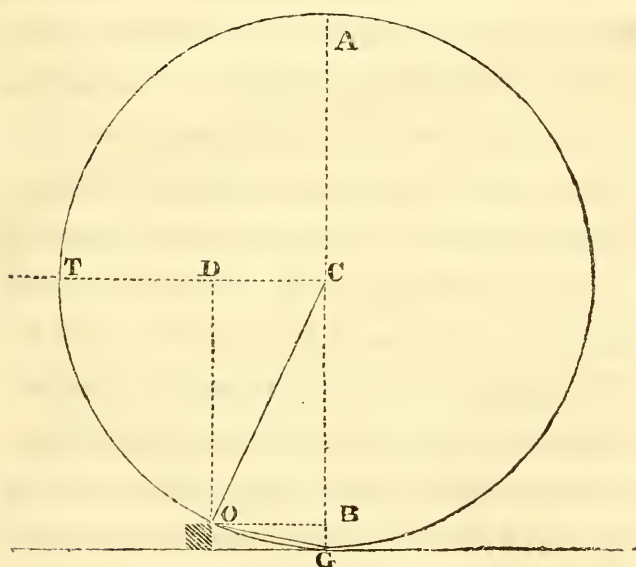
from the atmosphere were removed. These objects consist of,—First, the greater inequalities of the roads, which we call hills. Secondly, the lesser inequalities which everywhere present themselves; for even the best roads are not mathematical planes, but a succession of little risings and fallings. Thirdly, the resistance occasioned by the pressure of the wheels into the surface of the road; which is generally *something*, more or less, according as the road is more or less hard or soft, and more or less clean or dirty; which is commonly a cause of prodigious expenditure of the strength of the horses. Soft materials, dirt, dust, and sand, operate as a perpetual *hill* against the wheels. I have known a horse with a gig more fatigued by going a few miles on a firm sand sea-beach, when the wheels did not sink more than half an inch, than he would have been by going three times the distance on a hard road. The fourth cause of resistance is the air; which, to lofty coaches, covered with outside-passengers and luggage, is often very

great ; particularly when they *meet* a strong wind. It frequently happens that when a coach is travelling at the rate of nine miles an hour, it is opposed by a wind going as fast ; which forms a resistance equal to a wind going eighteen miles per hour. Therefore carriages should be so constructed as to meet with as little resistance of this kind as possible.

4. It were however absurd to speak of axle-friction in general terms. I have ventured an opinion that, in case of polished axles and brass boxes, with fine oil between them, which should be pure olive-oil, undiluted with rape-oil, which is of a viscous, glutinous quality,—axle-friction is not more than equal to one hundredth part of the power of the horses. But, in the case of clumsy wooden axles, smeared over with a composition of tar and cow-dung, the friction may be so considerable as to neutralize a fifth, a fourth, or even more, of the strength of the horses ; and so in proportion, as axles

are well or badly constructed. And as the substance interposed may be of a lubricous, or of a viscous and tenacious quality, the axle-friction will be less or greater—or, in other words, in that proportion the wheels will turn round with ease or with difficulty.

5. The action of a wheel as a lever, in overcoming an obstacle, may be demonstrated by the following diagram.



The circle represents a wheel 6 feet in

diameter—C being the centre ; O an obstacle 3 inches high ; G the ground ; T C the line of draft or traction. The lever is represented by the lines C O and O G ; of which C O is the arm of the lever ; and O G the opposite or lifting end ; O being the fulcrum on which the lever turns. In order, however, to ascertain the power of this lever, we must reduce each member of it to right angles with the lines of their respective directions. This will give us the line D O, at right angles with the line of traction, and the line O B, at right angles with the line in the direction of which the weight is to be lifted. Now, the power required to be applied to the line T, to balance 100 pounds at the end of the lever at B, is inversely as the length of the line D O is to that of O B. The length of the line D O is equal to one half the diameter of the wheel, minus the height of the obstacle, or 33 inches. The line O B, being the mean proportional between the two lines A B, which is 69 inches long, and B G, which is 3 inches long, is 14.3875 inches

long. (*Euclid*, B. VI. 13.) The question, then, may be stated thus :

Inches.	Inches.	Pounds.	Pounds.
As 33 :	14·3875 ::	100 :	43·589,

or little more than 43 pounds and a half; which is the power, or weight, falling over a single pulley, drawing in the direction T, necessary to balance 100 pounds, on a wheel 6 feet high, when opposed by a stone, or other obstruction, 3 inches high.

It will be obvious that, as the wheel rises over the stone, the line O D must gradually lengthen ; and the line O B must gradually shorten : consequently the resistance occasioned by the stone gradually decreases, until C rises perpendicular to O ; when it entirely ceases.

6. It is shown, above, that a wheel is really a mechanical power, operating as a lever ; and this philosophical advantage increases with the increased size of the wheel. But this advantage is more than counterbalanced by a disadvantage, which, after a certain

period, increases in a much greater ratio than the advantage ; which is the weight of the wheel itself. Because, to make a cart-wheel 10 feet high, it would be necessary to have the spokes not merely twice as long as for a 5-feet wheel, but they must be twice or thrice the substance, consequently four or six times as heavy ; there must also be more of them. The stock or nave must also be much heavier ; the axle much stronger ; and the fellies, as well as the tire-iron, must be both much stronger and twice the circumference : therefore such a pair of wheels, with the axle, would be a load of themselves. In order to convey a tolerably correct idea on this subject, I have calculated what weights, falling over a single pulley, would be equal to the resistance which wheels of different heights, carrying 100 pounds gross weight each, would occasion, when opposed by an obstruction 3 inches high ; and also by an obstruction of $1\frac{1}{2}$ inch high ; the wheel, in each case, being supposed to be in a state of rest.

7. An obstruction 3 inches high would cause resistance to wheels carrying 100 pounds gross each, as follows, viz.

To a wheel 6 feet, 0 inches, equal to $43\frac{1}{2}$ pounds.

5	—	8	—	.....	45	—
5	—	4	—	.....	$46\frac{1}{2}$	—
5	—	0	—	.....	$48\frac{1}{2}$	—
4	—	8	—	.....	$50\frac{1}{2}$	—
4	—	4	—	.....	$52\frac{1}{2}$	—
4	—	0	—	.....	55	—
3	—	8	—	.....	58	—
3	—	4	—	.....	62	—
3	—	0	—	.....	66	—
2	—	8	—	.....	$71\frac{1}{2}$	—
2	—	4	—	.....	$78\frac{1}{2}$	—
2	—	0	—	.....	88	—

An obstruction, $1\frac{1}{2}$ inch high, would cause resistance to wheels carrying 100 pounds gross each, as follows, viz.

To a wheel 6 feet, 0 inches, equal to 30 pounds.

5	—	8	—	.....	$30\frac{1}{2}$	—
5	—	4	—	.....	$31\frac{1}{2}$	—
5	—	0	—	.....	$32\frac{1}{2}$	—
4	—	8	—	.....	34	—
4	—	4	—	.....	$35\frac{1}{2}$	—

To a wheel 4 feet, 0 inches, equal to 37 pounds.

3	—	8	—	.....	39	—
3	—	4	—	.....	41	—
3	—	0	—	.....	43 $\frac{1}{2}$	—
2	—	8	—	.....	46 $\frac{1}{2}$	—
2	—	4	—	.....	50 $\frac{1}{2}$	—
2	—	0	—	.....	55	—

My object being to make these remarks as plain as possible, I have thought it best in these Tables to omit decimal fractions. The result of both evidently is, that the small advantage gained from the use of wheels above 4 feet 6 inches high, would not compensate for the inconvenience and increased weight of higher wheels.

It is also evident, from the latter Table, that the disadvantage of using small wheels does not increase *so rapidly* as in the former Table.

Another circumstance also is to be observed in these Tables as important,—that, in the latter Table, wheels require exactly the same power as those of twice the height in the former Table, or in exact proportion

as the obstruction is reduced. Hence the necessity of making our roads as smooth and as hard as possible.

8. It may be here proper to meet an objection that may possibly be raised, respecting the power which I have stated as necessary to carry a wheel over an obstruction. It may be said that the velocity, or momentum, which a coach may have acquired, is sufficient to carry the wheel over the object. Be it so. But the coach does, by going over this object, *lose* just as much of its momentum as is equal to the power necessary to carry the wheel over the object from a state of rest; and the horses must exert exactly so much *additional* power, to keep up, or recover, the speed of the coach, before their traces will be as slack as they previously were.



CHAPTER II.

1. *Conical Wheels injurious, both to Roads and Horses.*—2. *Conical Wheels wear out faster than Cylindrical ones.*—3. *Cylindrical Wheels and Axles best. Subject to only three-fourths the usual Toll.*—4. *High Wheels not disadvantageous going up-hill.*—5. *Broad-Wheel Waggon extremely injurious to the Roads. Projecting-heads of Tire-Nails.*—6. *Broad-Wheel Waggon not so advantageous to the Public Carrier as lighter Carriages.*

1. I KNOW no prejudice more firmly rooted than that in favour of *dishing* or conical wheels. Much has been written, and well written, to show, and to prove, the absurdity of the use of them, but hitherto with very little effect. I think the principles, and the effects of them, may be stated in very few words.

Carriages are intended to travel *straight forward* : they ought, therefore, to be furnished with wheels, the *natural tendency* of which should be to go straight forward. The same with a garden-roller : suppose any man were to have a garden or a field-roller, made six inches less in diameter at one end than at the other ; what would not even the wheel-wrights say of such a man ? Yet such an act would be a counterpart of their own, when they recommend broad conical wheels. The natural course of a rolling cylinder is a straight line ; and the natural course of a rolling cone is a circle. Let us reverse their natural courses : that is, let us make a cylinder travel in a circle, and a cone in a straight line. It must be obvious that, when each of these bodies is forced to travel contrary to nature, in the course of the other, there must be a constant dragging, or *twist*, on the ground, to keep it in its unnatural course. Such would be the case if a man were to drag a common garden-roller round in a small circle ; and such, too, would be

the case, if a man were to draw straight forward a garden-roller made six inches less in diameter at one end than at the other. The effect in both cases would be, *precisely, the same*. Each operation would be attended with prodigious labour; and the roller, in each case, by its twist on the ground, would break up and derange the gravel beneath. Now it is well known that the machine constantly in use, in numberless manufactories, as the best that has hitherto been invented for expeditiously and effectually grinding to powder the hardest and toughest materials, is a cylinder forced round in a circle. Therefore, as a cylinder moving in a circle is the best machine that the ingenuity of man has hitherto produced for pulverizing the hardest and toughest materials, and as this is effected by the twist or drag produced between the edge of the cylinder and the surface on which it rolls, and as the twist or drag is precisely the same in the case of a cone forced straight forward, I think I may be borne out in my opinion that a heavy wag-

gon, with broad conical wheels, is the most complete, the most efficacious machine that the art of man, in the present state of science, could construct, for grinding to powder the materials of our roads.*

2. And it is also true that, as the wheel grinds the road, in *that proportion* does the road grind the wheel. The tire of cylindrical wheels, therefore, would last probably many times as long as that of conical wheels.

3. It appearing, then, that the cylindrical wheel only has a natural tendency to roll straight forward, all carriage-wheels ought to be so constructed. Consequently the ends of the axles ought not to be conical or tapered, nor bent down, as they are now

* On looking over the Essay on Wheel-Carriages, published in the year 1813, by Richard Lovell Edgeworth, I find the same comparison in illustration of the effects of Broad Conical Wheels. But as the above is copied from my own manuscript, written twenty years ago, I hope not to incur the charge of plagiarism.

made; but the axle ought to be put into a lathe, and both ends turned, like the two ends of a spindle for mill-work, cylindrical; that is to say, of the same size or diameter at the ends as they are at the shoulders; and, of course, the boxes in the wheels should be cylindrical also.

It should be known that wheels of this construction are liable to only three-fourths of the usual toll, by the 55th Geo. III. chap. 119, at the discretion of the Trustees.

4. It is a general notion that high wheels act disadvantageously, going up-hill. That this is not the fact, is demonstrated by the ingenious Author before cited. He says, "Wheels, when ascending inclined planes, and when the line of traction is kept parallel to their ascent, notwithstanding they act as levers; yet, in this case, the action of the weight will increase with that of the power gained by the increased size of the wheel; which size, therefore, will be of no other consequence than, by lessening the friction,

as it does in wheels passing over planes.”* It seems the Author is showing that high wheels possess no philosophical *advantage* over lower ones, in ascending hills, other than they have on level ground ; but he also shows that neither have they any disadvantage.

5. It being shown, above, that the conical wheels of Broad-wheel Waggon are the same, in operation and effect, on the materials of the roads, as Drug-mills, it follows, of course, that all that portion of labour which is applied to the conical wheel, to keep it in a straight course, more than would be required to impel it in its natural circle, is so much power, not merely wasted, but most mischievously and most effectively applied in *grinding* the materials of the road into powder ; and as these waggons weigh, in summer, Eight Tons each, the silent mischief effected by these four drug-mills of Two Tons weight each, is great beyond

* Anstice on Wheel-Carriages, p. 32.

calculation. How much power is thus misapplied may be conceived, as it frequently requires ten of the heaviest horses to draw it; which is just sixteen hundred-weight each—a weight sometimes drawn by light horses, in stage-coaches, and at least at three times the pace!

Lest a total silence on the subject of projecting-heads to the Nails of wheels might be construed into an approval of their use, I am induced to make a remark or two upon them.—First, the effect of round projecting-heads, when the carriage is heavily loaded, the weight of the wheel with its load pressing *only on a point*, is, that inevitable destruction must ensue to the stone with which it happens to come in contract, even though such stone were firmly imbedded in the road. And, secondly, as they affect the horses, it is demonstrable that they are extremely injurious; because, in this point of view, it matters not whether these round knobs of iron be affixed to the wheels, or whether the wheels be smooth, and these knobs of

iron laid in the path of the wheels. Now, surely even the most inexperienced Carter, were he driving a waggon with smooth wheels, and seeing such knobs of iron strewed along the road in two tracks, would endeavour to avoid them, well knowing that his horses would draw their load more easily on any other part of the road. But these large heads are of no use whatever to the wheels; because, if the nails be properly countersunk, and the heads made *exactly* alike, for which purpose they should be made in a *mould*, and so adjusted to the hole in the tire as to hold fast at the *bottom* of the hole, the tire-iron will remain firm until it is reduced to the thickness of a penny-piece; whereas, if the nails hold only at the *top*, as this wears away, the tire of course soon becomes loose. Therefore, as projecting-heads to tire-nails are extremely injurious to the roads, and in a very great degree productive of increased labour to the horses, and as they are in every other point of view entirely useless, they

ought, I think, to be absolutely prohibited by Act of Parliament.

6. It is a happy coincidence that, frequently, what tends to private advantage tends also to the advantage of the public. I am glad to see these Gothic vehicles, which are objects of terror to the traveller, and which are destructive in the highest degree to the roads, gradually giving way to light carriages, drawn by four horses, and driven, as coaches are, by a man on the box. The owners have discovered the secret that horses in these carriages can draw nearly as much weight, five or six miles per hour, as other horses, nearly twice as heavy, can draw in heavy waggons, about two miles per hour.

Admitting the truth of the preceding statement respecting heavy waggons, it follows that, instead of being *encouraged*, as they now are, by *low tolls*, and in some cases by an *entire exemption* from toll, they ought to be subjected to a toll that would soon effect their extinction.



"LICENSED TO CARRY SIX INSIDE AND TWELVE OUTSIDE."

CHAPTER III.

1. *Modern Stage-Coaches ; unphilosophical. Supposed origin of the custom of persons riding on the tops of them.—2. Regulations for the security of Passengers suggested. —3. All Passengers by Public Carriages might be, and ought to be, protected from the weather.—4. Objections answered. Traces of Horses drawing ought to be placed horizontally. By the present construction of Coaches, Horses have to draw the same load, over the same obstruction, twice.—5. Centre of gravity of these Coaches simply illustrated.*

1. IN the construction and use of stage-coaches, notwithstanding the display of paint and varnish, I think there is less display of

any thing like science, or even common sense, than in most things about us. I have often questioned, whence the absurd custom of persons riding on the tops of coaches, over the heads of one another: and the solution is this: when coaches were first built, the top was considerably convex; a form which naturally presented itself to the builder, to turn off the rain; as appears by the annexed representation of a coach of about the middle of the last century.



This was undoubtedly the use and the sole use of that part of the carriage, most likely for a century after it was first invented. But it was, in my opinion, no more contemplated, by the early builders of coaches, that men should ride on the tops of them, than it now is that they should ride on the tops of sedan-chairs. The one is just as reasonable, just

as unreasonable and absurd, as the other. I have no doubt but that the custom originated thus : A coachman, driving along, overtakes a poor fellow on the road.—Coachman ! can you give me a lift ?—No. I'm quite full ; and I've no room on the box.—Oh ! let me get up ; I can ride on the top of the coach.—The poor traveller mounts aloft, and holds on as far as he is going ; and the coachman gets his SHILLING. This is the *secret*. Next time the coachman takes up *two* ; and, after a little time, the thing attracts the notice of the master, who perchance may like shillings as well as his man. Then follow arrangements for outside-passengers : first the foot-board behind the boot, to support the feet, and to prevent people from falling through between the boot and the body of the coach ; then the bridle, a strap of leather, one end fastened to one side, and the other end fastened to the other side of coachman's box, long enough for the outside-passengers to hold themselves on by it. All this I well remember. Then followed the side-irons ;

then similar arrangements at the back-part of the coach; and, lastly, the dickey-seat; and all this for the sake of the *shillings*—all an innovation, thus accidentally introduced, contrary to the use for which coaches were first made—sanctioned and regulated, too, by the sage authority of the British Legislature; who have decreed that only twelve persons besides the coachman, and perhaps half a ton of luggage, shall be thus mounted aloft—all in defiance of every principle of sound philosophy and common sense, and at the peril of the life of every traveller, inside or outside, who goes by these coaches. A gross reflection on the wisdom of the Legislature, and on the good sense of the Nation!

2. I would propose a very concise Act of Parliament, for the regulation of these coaches, to consist only of two clauses.

First. That no passenger shall be allowed to sit on any seat, cushion, luggage, or other thing, higher than five feet from the ground;

excepting only one person on the box with the coachman.

Secondly. That neither the roof of the coach, nor any luggage, nor any other thing, belonging to or about the coach, excepting only the coachman, and one person sitting by him, shall, on any account whatsoever, exceed eight feet four inches from the ground.

3. These two enactments would be sufficient for the public security; and ample scope would be left for the exercise of skill. If it be necessary to carry a large number of persons in one vehicle, they may be accommodated by a series of cross-seats, one behind another; which may be divided into compartments, for passengers of different degrees, and another compartment for luggage. And every person who travels ought to be protected from the weather. There can be no question but that many a poor traveller, who has not a second coat to his back, receives what may be called his death-warrant,

when exposed, for a winter's night, to frost and snow, on one of these coaches. The poor ought to be sheltered as well as the rich. The whole of our coach-system is unphilosophical and barbarous—unworthy of such an enlightened country as England.*

4. Here it may be objected that the consequence of lengthening the carriage and lowering the load will be, that the weight would follow more heavily after the horses. It would certainly be difficult to satisfy such objectors, who would be likely to be of the class called *Men of Experience*, that is to say, men brought up in a routine of practice, yet totally ignorant of principles. It seems as though they had a notion that the fore-wheel

* “It appears by the Newspapers that on the night of Tuesday the 25th of February, 1812, three outside-passengers were found dead on the roof of the Bath coach, from the inclemency of the weather. Neither money nor time is gained by exposing females and sickly people on the tops of coaches, in snow and rain, and to the hazard of their lives.”—EDGEWORTH on *Wheel-Carriages*, p. 146.

of a carriage, when *closely followed* by the hind-wheel, makes haste out of its way ; as a little boy at school, when pursued by a bigger boy, runs as fast as he can, for fear of being tripped up. All these notions about the necessity of horses being *close to their work*, and of wheels following as nearly as possible after each other, and of coaches that are loaded high running lighter than when the load is low, are completely refuted by the actual experiments of Richard Lovell Edgeworth. See his work.

It is very true that if the wheel-horses draw *upward*, by having the traces fixed to the carriage lower than the points at which they are attached to the hames, they have a firmer hold on the ground than they otherwise would have ; but in such a case the horses *lift* a part of the load, and what they lift they *carry* ; and what they thus carry, they *carry on their neck or shoulders*. I have known an instance of a man, who could not get his horse and cart up the ascent of a bridge, who, after much persuasion

from a by-stander, was induced to get upon the horse's back ; when the horse drew the load without difficulty. I have also myself observed, when going up a hill in a post-chaise, that the horse with the post-poy on its back drew more steadily, more firmly, and with *greater ease*, than the other. But no man, surely, would think of putting a weight upon a horse's *neck*, in order that he might have a firmer hold on the ground. Yet, inasmuch as any effect of this kind is produced by horses drawing *upward*, it is by *lifting* a part of the load with their *neck* or *shoulders*, and, consequently, with their *fore-feet* only. But, as such an act would scarcely find an advocate, it follows that the traces of all horses drawing ought to be placed in an horizontal direction.

But if traces are fixed horizontally, it matters not, as regards the draught of the horses, whether they are two yards long or six yards long ; neither, if carriages travelled only on roads that were perfectly flat and even, would it be important whether the axles of a coach

were six feet apart, or ten feet apart, as it might affect either the passengers or the horses; but it is clearly demonstrable that the present construction of stage-coaches is extremely *unfavourable* to the draft of horses; that is to say, a coach standing on four wheels, all as near together as they can possibly be set, and loaded similarly to the one represented at the head of this chapter. Suppose a coach, so loaded, to be travelling on fair even road, each wheel bearing its just proportion of the super-incumbent burthen; suddenly both the fore-wheels drop into a water-gully, perhaps six inches deep; when a part, and not an inconsiderable part of the load, which before rested on the hind-wheels, is thrown on the fore-wheels; whereby, when most disadvantageously circumstanced, as regards the horses, they are thus unfairly loaded: the fore-wheels are no sooner raised out of this gully, and the weight again fairly divided on both axles, when, in another instant, the hind-wheels drop into the same channel; and an equal part of the load,

which belonged to the fore-wheels, is thrown back upon the hind-wheels. The same weight, alternately bearing first on the fore-wheels and then on the hind-wheels, causes *double labour* to the horses; that is to say, the horses have, in crossing a gully, to draw the same, identically the same, weight *out of one gully twice*; first on the fore-wheels, and then on the hind-wheels. And the same *double operation* of the load takes place at every hole that may occur, on either side of the coach. That this alternation of weight is very great, is obvious to every person accustomed to ride on the tops of these coaches. The outside-passengers may be said to be in one constant state of vacillation, not only sideways, but backward and forward; and at every one of these backward and forward motions is the effect produced as above stated; which must ever be greater, in proportion as the base of the coach is small, and as the column of the coach is high; and still more, in proportion as weight is increased at the top of the column.

It may be said by Coach-Makers, and by Coach-Masters, that the above remarks are merely theoretical. I am however mistaken if it will not be admitted, by persons conversant with mathematics, that they amount to *proof* that the present construction and system of coaches is extremely unfavourable to the horses; and that the evil can be removed only by extending the base, and reducing the height of the column of the coach; or, in other words, by setting the wheels further apart, and by bringing down the load.

5. As my object is to produce a few plain and intelligible remarks, it is needless to enter into a discussion about the centre of gravity. Every man of common sense knows that a waggon, with a ton of lead in its bottom, and a ton of hay upon the lead, would travel very safely; whereas, if the lead were on the top of the hay, it would be very easily upset. Yet this is just the condition of one of our coaches:—light wheels

and light frame-work ; a light body, with four or at most six persons in it, and over their heads at least a ton, no matter whether of lead or of human beings ; twelve to sixteen persons ; and not this only, for the roof is frequently covered with luggage, and that, again, crowded with passengers !

I hope to be excused for once more exclaiming against this irrational, absurd, and dangerous system of public conveyances ; which calls loudly for the wise and judicious interference of the Legislature.

CHAPTER IV.

1. *A new principle suggested, as important in the Construction of Carriages, viz. the DIVISION OF WEIGHT, or POWER, by the use of a greater number of Wheels for the same load; thus causing less labour to the Horses and less injury to the Roads.—2. Carriages should press the road with the least possible weight on any one wheel. Less labour required to draw several wheels in succession, over an obstruction, than to draw one wheel, carrying the same amount of weight, over the same object.—3, 4, 5. Illustration of this Theory.—6. Breadth of wheels no security against the destructive effects of pressure. Broad Wheels on paving-stones.—7. The principle of light pressure should be carried as far as may be consistent with public convenience.—8. Light Waggon for one horse suggested.—9. Six-wheel and Eight-wheel Carriages recommended. Were in use some years ago. Were remarkably easy to travellers.—10. Had one defect in construction.—11. Carried enormous loads with four horses.*

1. THERE is a principle, which I do not remember to have seen noticed, and which

I consider of great importance, as applicable to this subject. It may be called **THE DIVISION OF WEIGHT**, or, more philosophically perhaps, **THE DIVISION OF POWER**: that is to say, the division of the power, which any carriage may possess, to crush or destroy the materials of the roads; and the division of the power, which any carriage may possess, to resist the power of the horses drawing such carriage.

A man can break an ordinary stick, an inch in diameter, across his knee; but, if he tie ten of these sticks together, he could not break them if he tried ten times, nor if he tried a thousand times; although, by these thousand efforts, he might have broken a thousand such sticks separately. A stone might be of such a size and texture that a strong man with a large hammer might break it into pieces at one blow; while a boy with a small hammer, striking it with one-tenth part of the force, might strike it a thousand times, applying in the whole one hundred times the power upon it that the

man would have done, without producing the same effect.

So it is with the pressure of wheels on the materials of the roads. Suppose a stone, the size of a man's fist, to lie detached on a firm part of the road, and a waggon-wheel, pressing with the weight of two tons, were to pass over it; the consequence would be that it would crush it to powder. But suppose these two tons to be distributed into forty wheelbarrows, of one hundred-weight each, and they were to pass over it in succession; the only effect likely to be produced would be a trifling rounding of its corners: nor would probably five hundred such wheelbarrows, or twenty-five tons, crush the stone so completely as the single waggon-wheel. Nor do I think that five hundred gig or one-horse-chaise wheels, of four hundred-weight each, in all one hundred tons, would so completely destroy the cohesion of the stone, as the single crush of the heavy wheel.

2. Conceiving, therefore, that the destruc-

tive effect of pressure on the roads increases, from the lowest weights to the highest, in a very rapidly increasing ratio, I think that all reasonable ingenuity should be exercised, so to construct our carriages as for each wheel to press the road with the least possible weight that the public convenience will allow. Besides, it is considered a mathematical axiom, that action and re-action are equal. If I fire a gun, the breech is pressed against my shoulder with exactly the same force as that with which the shot is discharged. So, in crushing a stone with a heavy waggon-wheel, just so much of the power of the horses is expended and misapplied upon it as is necessary to overcome the resistance occasioned by its cohesion, or the firmness with which its parts were held together; whereas, if these two tons were divided upon eight wheels, of five hundred-weight each, the horses would draw them *over* the stone, one after another, with perhaps a tenth part of the exertion or expenditure of strength that was necessary to break the stone,

3. Were it necessary, I could adduce practical proof of the soundness of this theory. Some years ago the Brewers in Bristol had, most of them, two-wheel drays, carrying four barrels each, and drawn by one horse, for sending out small quantities; when a friend of mine, at my suggestion, had a four-wheel carriage made, the hind-wheels of which were three feet high, and the fore-wheels about two feet four inches high; the carriage, complete, weighing about eight hundred-weight; it being about eight feet long in the bed, to carry three barrels on each side; which six barrels, at four hundred-weight each, weighed twenty-four hundred weight: total, thirty-two hundred-weight. This was found easy work for one horse. Although firmly protested against by the *Man of Experience* whom my friend employed, as a carriage that never would answer his purpose, it was quickly imitated by the other Brewers; and these carriages are found so completely useful and convenient, that now (1820) they are more fre-

quently seen in the streets of Bristol than any other sort. I have also proved, by abundant practice, that three horses can draw a ton more gross weight, on a well-constructed four-wheel carriage, than they can upon one with two wheels. I am not aware that this is to be accounted for on any other principle than that which I have just brought forward. And as this increased facility, on the part of the horses, is owing to the lighter pressure of the wheels on the ground ; so, in proportion as the labour of the horses is lessened, is the action of the wheels on the roads ; or, in other words, in that proportion is the wear and tear of the roads diminished.

4. Lest the principle I am desirous of establishing should not be clearly understood, I will endeavour further to explain it, with all possible perspicuity. I will suppose the two-wheel beer-carriage, above mentioned, to weigh ten hundred-weight, and the four barrels of beer to weigh sixteen hundred-

weight : total, twenty-six hundred-weight. Each wheel, then, pressed the ground with a weight of thirteen hundred-weight, which was the weight that the horse would have to draw out of every hollow, and over every obstruction, at *one* effort ; whereas, in the case of the small four-wheel carriage, the horse would have to overcome the resistance of only eight hundred-weight at one time ; and it is proved by abundant practice, for many years past, that he can draw two of these weights in succession over each obstruction, one behind the other, that is to say, one on the fore-wheel and one on the hind-wheel, with *less labour* than he can draw thirteen hundred-weight over each obstruction at once.

5. The London Porter-Brewers would find exactly a similar result from a like change. One of their two-wheel drays weighs about seventeen hundred-weight ; on this they load three butts of porter, at twelve hundred-weight each, say thirty-six hundred-

weight: total, fifty-three hundred-weight. The horses have half this load, or twenty-six and a half hundred-weight, to resist, at every obstruction that either of the wheels may have to encounter. A four-wheel carriage *need not weigh more than seventeen hundred-weight*, to carry *four butts*: total, sixty-five hundred-weight; of course the horses would never have to encounter more than sixteen and a quarter hundred-weight at any one obstruction, at one time. The Brewers would find their horses draw *four butts much more easily*, on a well-constructed four-wheel carriage, *than they now draw three*.

In the construction of a four-wheel carriage for four butts, it should be remembered that, whereas now each wheel has to carry *half* the massy bed and one butt and a half, —then, in the case of a four-wheel carriage, as the bed would have *two bearings*, the side-pieces or blades need not be half, nor a quarter, so heavy as the present; and as each wheel would have to carry only its *fourth* of a light bed, and only *one butt*, it should,

as well as the axles, be made proportionably light. For such a carriage I would suggest four feet as a suitable height for the hind-wheels, and three feet for the fore-wheels. And I am firmly of opinion that neither the paving of the streets nor the gravel of the roads would suffer a tenth so much, from four wheels of sixteen and a quarter hundred-weight each, whether wide or narrow, as from two wheels of twenty-six hundred-weight each. It is the intensity of pressure that does the mischief.

6. It may indeed be argued that twenty hundred-weight, on a six-inch wheel, presses with the same weight, on any one point, as ten hundred-weight on a three-inch wheel. This would be the fact if the roads were perfectly flat and smooth, and if the wheels were perfectly cylindrical. It is possible to make wheels perfectly cylindrical ; but it is not possible to make roads perfectly flat and smooth ; therefore even a cylindrical wheel would rarely press *alike* with the whole

breadth of its rim, on the road; but it would press most heavily with one edge or the other, or with some intermediate point. Hence it follows that, to allow weights to increase with an increased width of wheels, is to admit a principle which, however sound in theory, is not sound in practice. But, as applied to the pressure of wheels on roads, as well as to the resistance they would cause to the horses, the principle is not sound in theory; because six-inch wheels must pass over twice as much loose and detached matter as three-inch wheels; and, whenever a six-inch wheel meets a single stone, the effect on that stone would be precisely the same as though the wheel were only three inches wide. In this point of view the evil of admitting this principle would be two-fold, as it concerns both the roads and the horses. First, the evil of increased weight, which I have alluded to in the first section of this chapter; and, secondly, the increased breadth of the wheel, whereby twice the quantity of loose matter would come within its destructive influence.

But this theory is unsound in another point of view, as applied to roads. We are not to consider roads as solid rocks, but as quantities of matter, very moderately cemented together, and in some cases not cemented at all; therefore a GREAT WEIGHT, IN ONE ROLLING MASS, has a tendency to *disturb* the entire bed of the road, whether it be on a six-inch wheel or on one of sixteen inches. Under all these considerations, I am satisfied that the only grand desideratum, on behalf both of the roads and the horses, is LIGHT PRESSURE. And therefore any dependance on breadth of wheels, as a security against the destructive effects of pressure, is in my opinion fallacious.

I wish here to be understood as applying these remarks under a supposition that wheels were made upon the best philosophical construction; that is say, perfectly cylindrical; and that they stood perfectly upright or vertical. The present system of broad wheels I consider a system of mere mockery. I suppose that not one nine-inch wheel in one

hundred bears on the ground more than three inches : that is to say, if such a waggon were to be placed on a paving of flagstones, that the parts of each wheel in contact with the stones would not exceed three inches. It is very true that when we follow such a waggon, on a Turnpike road, we often see a track nine inches wide. Now these wheels are round in every direction ; and, generally speaking, the roads are round also : it is therefore *impossible* for these wheels to leave a nine-inch track, by *any other* operation than that of impression, or *squeezing in*. Whenever therefore such a track is any thing more than an impression in the dirt, it is an impression into the road itself, by the last-mentioned operation, viz. a disturbance or disarrangement of the body of the road.

I have called it a system of mockery ; such it really is : for there seems the most perfect understanding between the mockers and the mocked. I have even known Trustees of Turnpike-roads make gratuitous concessions

of *half the tolls* in favour of broad-wheel waggon; contrary, as it appears to me, to their own special Act of Parliament.

The foregoing reasoning is also applicable to the streets of London. It would be ridiculous to insist that any advantage can possibly result from the use of broad wheels on these paving-stones, nearly every one of which is round on its upper surface. A six-inch wheel of a brewer's dray, in contact with one of these stones, is merely a collision of two convex bodies, each extremely hard, one against another—I might almost say spherical bodies; for that is the real figure of what the law supposes to be a conical wheel; and it is nearly the figure of these stones: consequently the surfaces in contact, at any one time, are extremely small; little more than the surfaces in contact of two eggs in a basket.

7. If it be admitted as a principle of importance, for the preservation of our public roads, that the thousands of tons of commo-

dities of all sorts which are constantly rolling over them should be divided out on as many wheels as possible, it remains to be considered how far the principle can be carried, consistently with public convenience, and by what means it can be effected.

8. There are two means by which this can be effected : first, by light waggons for one horse ; and, secondly, by the use of carriages of six or eight wheels.

One-horse-waggons fully embrace the principle ; and the labour of the horses would be much more efficiently applied than at present. If light one-horse-waggons were constructed, to weigh eight hundred-weight each, and these were charged with a load of sixteen hundred-weight each, a good ordinary cart-horse would travel England over with such a load ; drawing just as much *nett weight* as the ten horses in a heavy waggon take each in *gross weight* ; and the roads would never have a pressure, on one point, exceeding six hundred-weight ! The only objection to such

carriages that I see is, that each must be attended by a man. But were they adopted, roads would last—I will not say ten times as long—I think they would last a hundred times as long as they now do. Carriages so constructed ought therefore to pass at the lowest possible rate of toll.

9. The next mode is by the use of carriages with six or eight wheels. About twenty years ago there were several stage-coaches constructed in this manner. * Two eight-wheel coaches plied some years between Bath and Bristol, and they were so constructed that each wheel supported its share of the load, carrying its proportion, and no more, over every obstruction : the consequence was, that when a wheel passed over a stone two inches

* It does not appear that these coaches were introduced on the ground of any philosophical principle, but merely as a whim of the day. Even Richard Lovell Edgeworth, alluding to the existence of six-wheel and eight-wheel coaches, says, "Eight wheels have been applied to carriages, but it is difficult to comprehend upon what principle."

high, the middle part of the carriage rising only an eighth part of two inches, or one quarter of an inch, they were perhaps the easiest coaches, to passengers, that ever were sat in.

10. They had, however, one defect in their construction: which was, that the two hinder-axles being fixed, whenever the coach varied from a straight line on the road, the hindermost pair of wheels must have been dragged sideways. How the six-wheel coaches were circumstanced in this respect, I had no opportunity of observing.

In constructing carriages with any number of axles, the object required is for the machinery to be so contrived, that whenever the carriage is going in a circle, if a line were drawn through each of the axles, all the lines should meet at one point; which point is the centre of the circle in which the carriage is travelling. In this case, every axle would move fairly, without any drag sideways.

11. There is now living in Bristol a man who constantly drove one of these eight-wheel coaches, between that city and Bath. He informs me they carried fourteen inside and sixteen outside passengers, besides luggage. With this enormous load he used to go between the two cities, twelve miles of road, at that time much more hilly, and in worse condition than at present, with four indifferent horses, in two hours. I understand the reason why these two coaches were discontinued was, that as they carried at a low price, they were often filled with a crowd of mean people; which disgusted the more respectable travellers, to whom alone the proprietors could look for permanent custom: the coaches of course dropped. This, however, does not affect their principle as machines: on the contrary, the report of them tends greatly to confirm the theory I have attempted to establish.

CHAPTER V.

1. *Friction does not increase with the increase of the rubbing-surfaces : proved ; consequently not with an increase of the number of axles. Practice of the Author.*—2. *Practical use of many wheels.*—3. *Proposed remedy for the old defect in the construction of Six-wheel and Eight-wheel Carriages, illustrated by engravings.*—4. *Causes why the Six-wheel and Eight-wheel Coaches were discontinued.*—5. *Suggestions for obviating these causes.*—6. *Matthews's Patent Coach.*

1. HERE it may be proper for me to meet an objection that we frequently hear advanced against four-wheel carriages, viz. that, having twice as many axles as a two-wheel carriage, they have *proportionably* more friction. The position stands thus : that friction increases as the rubbing-surfaces increase, without regard to the weight of the sliding-bodies. Let a man take a common brick, nine inches long, four and a half inches

wide, and two and a quarter inches thick ; let him draw it along a board, by means of a line, over a single pulley at one end of the board, and a weight falling perpendicularly at the end of the cord. First, let him draw it along upon its broad side : he will find that it will require a certain weight to draw it along the board. Then let him draw it along upon its edge. He ought, upon the above supposition, to find exactly *half* the weight sufficient, because the brick is now sliding upon exactly one half the surface. Then let him draw it along upon one of its ends, the brick standing upright. He ought now to find one quarter of the weight he first used sufficiently powerful, because the brick now slides upon exactly one-fourth of the extent of surface that it did in the first instance ; but, instead of these results, he will find that the brick will require precisely the same weight to draw it along in each of these experiments, provided the brick be alike on all sides, not presenting any sharp points to stick in the board on one side more than on

another. Therefore the friction upon any number of wheels and axles, carrying the same weight in the whole, is exactly the same.

I have a light waggon, about seventeen hundred-weight, with turned axles, and brass boxes bored to fit them; which requires about an ounce of oil at a time—more would be wasted. With this waggon, two horses constantly fetch forty-eight bushels of coals from the pit, at least two tons; they also fetch as much manure as the waggon will hold, frequently more than two tons—each several miles on hilly roads.

I also use olive-oil for my carts, dung-carts! Perhaps my waggon, two carts, and a gig, may consume from two to three pints of oil in the course of a year, at fifteen pence a pint—not one shilling a piece for each carriage.

I am satisfied that my two horses would travel with two tons nett weight on my waggon, stage for stage with any road-waggon in England in which the horses draw on an

average not more than eleven or twelve hundred-weight each, nett weight. Nay, my Carter says he is certain that these two horses could take forty-eight bushels of coals (two tons,) to London, one hundred and twenty miles, in four days, without any injury or extraordinary fatigue. I mention this to show how completely the horses are above their work. Now, although these horses might possibly draw this load in a cart, it would, I think, never enter into the head of a reasonable man that they could go thirty miles a day with it for four days together. There must, then, be an intrinsic difference in favour of the waggon, whereby the horses have such high command over their work, which is simply this: whereas with a cart of the same weight, with wheels, four feet eight inches high, the horses must make an exertion equal to 1609 pounds, to draw one wheel over an obstruction 3 inches high; they have, in the case of the waggon the fore-wheels of which are four feet high and the hind-wheels five feet high, to make an

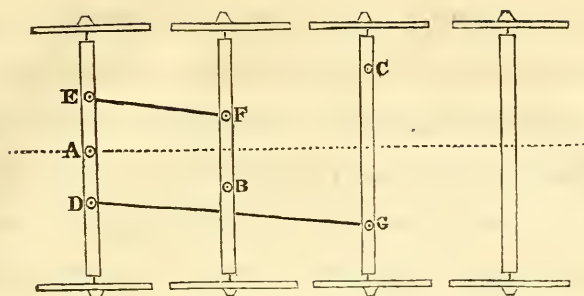
exertion equal only to 883 pounds to draw one of the fore-wheels, and an exertion equal only to 773 pounds to draw one of the hind-wheels over such an obstruction. And if the wheels were increased to six or eight, I suppose the horses would draw the same weight with nearly a proportional increase of facility. And the difference, as regards the roads, would be such as I have before explained.

Another thing is also obvious, viz. that if these two horses drew this load in two single-horse carts, each of half the weight of the waggon, each horse would have exactly the same exertion to make at any obstruction, as though the two horses drew the whole load in one cart. Hence it is evident that the principle of division is equally important, whether the load be great or small, or whether it be drawn by a number of horses or only by one.

2. But, that axle-friction, when the parts are oiled, is very small, is proved by the enormous weights of coals and iron-ore

drawn by one horse on iron rails, or tram-roads, in a series of small four-wheel carriages, one behind another, at least six in number, carrying a gross weight of several tons. Here, although the horse has to overcome the friction of twenty-four axles, yet, the major obstructions being in a great degree removed, he is enabled to draw these heavy weights.

3. It would be easy to construct six-wheel and eight-wheel carriages in such a manner that, when turning corners, all the axles shall be so many concentric radii; or, in plain words, in the case of an eight-wheel carriage, when the fore-axle shall lock three degrees, the second axle shall lock two degrees, the third axle shall lock one degree, and the hindmost axle shall be fixed.



The above figure is intended to represent the machinery necessary to effect the locking of the wheels of an eight-wheel carriage, as above described. A is the perch-bolt of the fore-axle; B the perch-bolt of the second axle; C the perch-bolt of the third axle. E F is an iron brace, with a bolt and eye at each end of it, to communicate motion from the first axle to the second axle; D G is a similar brace, to communicate motion from the fore-axle to the third axle. As the second axle is to move two degrees when the fore-axle moves three degrees, it will be necessary that the distance from B to F be to the distance from A to E as three is to two, or half as much again; and as the third axle is to move one degree when the fore-axle moves

three degrees, it will be necessary that the distance from G to C be to the distance from A to D as three is to one, or three times as much. Now, as it will be necessary, for the steadiness and well-working of this machinery, that the braces be set as wide apart as possible, the distance from the perch-bolt to the brace in the third axle must be first settled, which I have taken at 40 inches: this will give $13\frac{1}{3}$ inches for the distance from A to D; and as it is necessary, for the even draught of the carriage, that the brace-bolt E be exactly the same distance from the fore perch-bolt as the brace-bolt D, the distance from A to E will also be $13\frac{1}{3}$ inches; and the distance from B to F, in the second axle, will of course be $13\frac{1}{3}$ inches and half that quantity, or 20 inches. The bolts must be placed exactly at equal distances from the centre-line of the carriage, in each axle respectively, which will cause the second and third axles to act with equal force against each other, whereby the draught on the fore-axle will be equal.

For a six-wheel carriage the same machinery would answer very well, omitting the hinder-pair of wheels. It would, however, be better if it could be so managed as for the third or hinder axle to be fixed, and for the first and second axles only to move, as thereby the carriage would turn in less compass. It may be done, but not, by any plan that I am aware of, without causing an unequal draught on the fore-axle, because the second axle must be moved by a brace on one side of the perch-bolt of the fore-axle; but in this case there would be no other brace to act against it.

Or, for a six-wheel carriage, the middle axle might be fixed, and a *contrary motion* might be communicated from the fore-axle to the hinder-axle by means of two rods or braces, one passing from the near-side of the fore-axle to the off-side of the hinder-axle, the other passing from the off-side of the fore-axle to the near-side of the hinder-axle, crossing each other in a mortise in the middle of the middle axle.

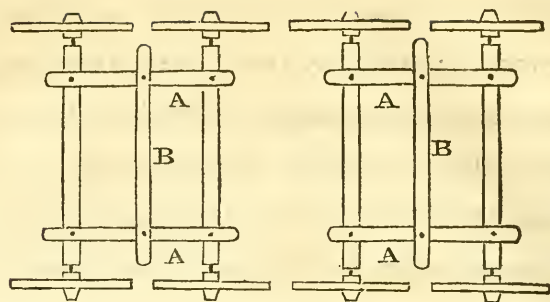
Each of these rods must have a length of chain at each end of it, to work on two semi-circles, to be fixed on the *insides* of the fore and hinder axles, which should not be of less diameter than three feet. Hence the hind-wheels would in all cases follow in the same track as the fore-wheels, and the carriage would turn in a *very small* compass ; but I think it would be heavy and noisy, and would be very liable to get out of order.

Or, for a six-wheel carriage, if the braces in the above figure were brought to the distance of only 8 inches on each side of the perch-bolt of the fore-axle ; and the perch-bolt and brace in the second axle were brought to a distance of $13\frac{1}{3}$ inches, which bears a proportion to 8, as 5 is to 3 ; then, when the fore-axle locked 5 degrees, the second axle would lock 3 degrees ; and as the distance from C to G in the third or hindermost axle is 40 inches, and the distance from A to D in the fore-axle would be 8 inches, they would bear a proportion to each other, as 5 is to 1 : consequently, when the fore-axle locked 5

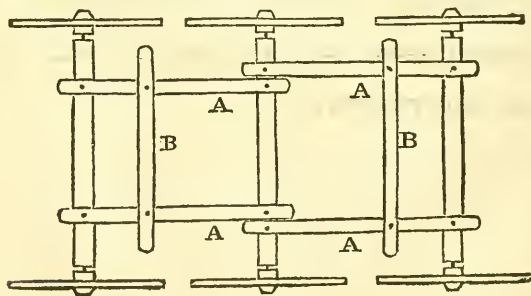
degrees, the third or hinder-axle would lock one degree; whereby the middle axle would always form equal angles with the other two axles; that is to say, the fore-axle would lock as much more than the second axle, as the second axle would lock more than the third axle; consequently, the three axles would always form concentric radii, or nearly so; and the carriage would turn in very little compass, as the locking of the third or hinder-axle would be very trifling.

As, in this latter application of the machinery, the two bolts in the middle axle would be each within seven inches of the center-line of the carriage, attention must necessarily be paid to the strength of the middle axle, near these bolts.

It is scarcely needful to observe that, in all these dimensions, the center of each bolt is to be understood.



The above figure is intended to represent the frame-work necessary for producing an equal bearing of the load on each wheel of an eight-wheel carriage. A A A A are four pieces of wood, bearing on the first and second, and on the third and fourth axles; B B are two pieces, bearing again on these. These are what I believe the workmen call the pillow-blocks, on which the bed of the waggon or the springs of a coach are fixed.



The above figure is intended to represent the frame-work of a six-wheel carriage, whereby each wheel would bear exactly one-sixth part of the load. On which I need only observe that the two pillow-blocks marked **B** must be placed one third of the distance, from the fore and hind-axles, respectively, to the middle axle; consequently the fore-axle would take two-thirds of the weight of the fore-end of the body, and the middle axle would take one-third; and the same of the hinder-part; therefore each axle would bear one third of the whole load.

4. Should it ever, hereafter, be deemed expedient to have recourse to six-wheel and eight-wheel coaches, it must be kept in mind that the principle I have insisted on is, that an eight-wheel carriage would cause less labour to the horses, and less injury to the roads, than one of six wheels; each carrying the same gross weight—that one of six-wheels would cause less labour to the horses, and less injury to the roads, than one

of four wheels ; all carrying the same gross weight.

But the six-wheel and eight-wheel carriages being favourable for a long body, the passengers sitting sideways, this was the form, I believe, always used for these carriages some years ago ; which affords several causes for their getting out of use. One I have before given, in the case of the Bath and Bristol coaches ; another was the circumstance of the passengers sitting sideways, which was very unpleasant, particularly by night ; another was, that these bodies, which were ten or twelve feet long, afforded the proprietors and their servants opportunities of carrying enormous loads of luggage on the top, beside a crowd of passengers within and without, with which the poor horses were expected to travel as fast as with lighter coaches. Of course it is no wonder if these long coaches, so unmercifully loaded, unfairly acquired the reputation of *killing the horses*. Passengers were disgusted at being confined, during a dark night, with a large

promiscuous company ; the side-motion at the same time being very unpleasant ; and there being nothing to lean against, except for those who could catch the ends of the long seats. Under all these circumstances, it is no wonder that these coaches soon disappeared.

5. I see no reason why a coach-body of nearly the common construction might not be made wide enough to carry four passengers on one seat, with a stuffed partition in the middle, from the seat to the top of the coach, a foot or fifteen inches wide ; which would give every one a *corner*. A coach thus formed need not exceed five feet six inches in width, provided it were as wide, at the backs of the seats, as across from door to door ; or, if this were inconvenient, a carriage might consist of one common six-in-side body, with another body attached, for passengers at an inferior price, with two seats, to carry four persons each ; this body to have a fixed covering or *head*, and cur-

tains to draw around at pleasure ; as is the case with two or three public coaches that travel out of Bristol. This would make fourteen passengers, besides one on the box, with the coachman ; in all sixteen persons ; enough, surely, with luggage, for four horses to draw eight or nine miles an hour ! Luggage might either be stowed below, or in a chamber between the two bodies, or under the coachman. But on the top should be put neither passenger nor luggage.

It is scarcely in human nature to resist temptations of gain : it is therefore necessary for coach-masters to *limit the accommodations* of their carriages to such a number of passengers as their horses can properly draw ; otherwise their servants will take up every twelve-penny passenger that offers on the road ; and, let the construction of their vehicles be what it may, they will find them **KILL-HORSE COACHES.**

6. Perhaps, by the above suggestions, I may be thought to be proposing an in-

fringement on Matthews's Patent. I have seen his coaches and have read his specification, and I cannot clearly see on what ground this Patent stands. It contains no *new principle*. Stowing luggage under foot is of very old date. Milton's Patent was precisely this. And I have myself seen travelling-carriages, many years ago, with chambers for luggage under the floor of the carriage. Nor is there any thing new in people riding back to back, the seats being placed longwise: what is called the Outside Irish Car is so constructed. I have also seen machines of this form for conveying military. I have also seen outside-seats, back to back, placed crosswise; the double seat forming one luggage-box. We have seen two close bodies on the same wheels, two open bodies on the same wheels, one close and one open on the same wheels, others with seats behind and seats before. And this coach appears to me to differ from others merely in the modification of the seats, but without any thing, in principle, that has a claim to

novelty. It should also be known that to every Patent is attached the following condition, on the part of the Patentee, viz. "That he is the first, and sole, inventor thereof; and that the same hath never been used, nor practised, by any other person or persons whomsoever." Now most of the particulars specified, on which Matthews's Patent is founded, have been used and practised before: therefore I conceive that, so far, his Patent is unavailing.

CHAPTER VI.

1. *Comparative effect on the Horses, by the use of Carriages of Two wheels, of Four wheels, of Six wheels, and of Eight wheels, all carrying the same gross weight. Illustrated by a Table.*—2. *Fore-wheels the pioneers of the hinder-wheels.*—3. *The roads doubly interested in the question of heavy or light pressure.*

1. I WILL now proceed to state the practical difference, to the horses, in the use of carriages of two wheels, of four wheels, of six wheels, and of eight wheels ; each carrying thirty hundred nett weight. I will not suppose any difference in the weights of the respective carriages ; because, as the number of wheels increases, the height, the strength and weight of each wheel would be proportionably reduced. Eighteen hundred-weight is about the weight of a strong cart ; it is also the weight of a light waggon ; nay,

heavier than one of my own, which carries from two to three tons. It is also just the weight of a strong stage-coach, licensed to carry six inside and twelve outside passengers; the *average* gross weight of which, when loaded, may be taken at forty-eight hundred-weight, although they are sometimes heavier. However, for the sake of calculation, I will suppose a set of loaded carriages, each of the weight of forty-eight hundred-weight.

A Table, showing the power in weights descending over a pulley, equal to the resistance of one wheel of a carriage of several different constructions, when opposed by an object three inches high, and when opposed by an object an inch and a half high. The carriage in every case to be forty-eight hundred-weight, gross weight.

Height of Wheels.	Weight with which each wheel presses the road.	Weight equal to the re- sistance of one wheel, when oppo- sed by an object three inches high.	Weight equal to the re- sistance of one wheel, when oppo- sed by an object $1\frac{1}{2}$ in. high.
ft. in.	cwt.	lb.	lb.
A Carriage with two			
wheels	4 8 ..	24 1355	 916
A four-wheel Coach,			
as at present con-			
structed :			
The fore-wheel 3 4 ..			
12 833 552			
The hind-wheel 4 8 ..			
12 677 $\frac{1}{2}$ 458			
Six-wheel Carriage,			
all the wheels of			
the same height 3 4 ..			
8 555 368			
Eight-wheel Carriage,			
all the wheels of			
the same height .. 2 8 ..			
6 482 313			

2. Wishing to clear objections as I go, it may be proper to remark, that the fore-wheel is the pioneer of the hinder wheel. If it meet a stone, it either breaks it down,

in some degree, or pushes it aside ; or, if it be heavy dirt, it clears the way ; whereby the hind-wheels have, rarely, much resistance of this kind, if the wheels follow well. It is fifty to one if the hind-wheel meets the same obstruction, under precisely the same circumstances, as the fore-wheel did, excepting only on hard pavements. And even these reduced obstructions are to be encountered at renewed efforts, as before explained. The coachmakers accordingly find the fore-wheels of coaches wear out much faster than the hinder ones.

Taking the above table to be correct, I think there can be but one conclusion drawn from it, viz. that carriages bearing the *same weight* may be drawn with greater ease, in proportion as the number of wheels is increased. In the case of the coach, for instance : the fore-wheel of a common stage-coach requires a power to draw it over an obstruction, whether high or low, compared with the power necessary to draw the fore-wheel of an eight-wheel coach of

only two feet eight inches high, each coach carrying the same weight, as seven is to four.

As the very principle on which my reasoning proceeds is to "Divide and Conquer," that is to say, as any given power will overcome a *much greater* weight, when that weight is divided, than when it is entire,—it is almost superfluous to admit that the sum of the powers required to draw four wheels of an eight-wheel coach, over an obstruction in succession, is greater than the sum of the powers required to draw the fore and hind-wheels of a coach, as at present constructed, each coach weighing forty-eight hundred-weight: the former requiring, for a 3-inch obstruction, 1928 pounds; and the latter requiring only 1510 pounds. I will take a fourth of these weights, to reduce them within the power of a man: that will give, on account of the four wheels of an eight-wheel coach, four several weights of 120 pounds each; and, on account of the two wheels of a four-wheel coach, the

two several weights of 208 pounds and 169 pounds. Now, by how much a man could lift 120 pounds, four times in succession, more easily than he could lift the two several weights of 208 pounds and 169 pounds, once each, in succession,—by so much could the horses draw the eight-wheel coach more easily than they could draw the four-wheel coach, over such obstruction.

The force of this reasoning must I think, be obvious to every person conversant with such matters : it applies to labour of every kind. A man can dig a much greater quantity of ground in a day, with a spade considerably *below* his strength, than he can with one equal to his strength. Two men at a crane can lift a much greater quantity of goods to a given height, in the course of a day, in such portions, as they can lift with ease at each time, than they can if the crane be so loaded as to oblige them to exert their strength to the utmost. And I think it must be equally obvious that four horses, drawing an eight-wheel coach with wheels two feet

eight inches high, can apply a power equal to 482 pounds four times, in drawing such coach over an obstruction three inches high, with much less labour than that which they must exert in two efforts equal to the several weights of 833 pounds and $677\frac{1}{2}$ pounds, in drawing the two wheels of a four-wheel coach, as at present constructed, over a similar object; notwithstanding the amount of the power in the four efforts in the former case, exceeds that of the two efforts in the latter case.

3. As the foregoing calculations concern the roads, the consideration is, in my opinion, of high national importance: for it must be kept in mind that the respective powers, as set down in this last table, as necessary to draw any wheel over an obstruction, are actually exerted. The *road itself* is the fulcrum; and the horses' limbs are the levers. The road itself is acted against by the horses' shoes, in proportion to the pressure and grinding property of the wheel; and this

takes place all the way down, from the heavy waggon, with its drug-mill-wheels, to the light gig. It is ROAD *against* ROAD; action and re-action being, in every case, *exactly* equal. Therefore the road must ever be considered as *doubly* interested in this important question.

CHAPTER VII.

1. *Tolls should be imposed on Wheels only, without regard to the number of horses drawing any carriage.*—2. *A liberal number of horses, to any carriage, advantageous to the Road.*—3. *Eight-Wheel Carriages, to weigh forty-eight hundred weight gross, ought to be encouraged by low tolls, as most advantageous to the Proprietors, and to the Roads.*—4. *If intensity of pressure on each wheel be removed, the form or width of the wheel is of little consequence.*—5. *Cylindrical wheels preferable, even for the lightest weights.*

1. IT is a maxim with me, that sound practice must ever accord with sound theory. Now if it be admitted that the theory I have attempted to establish be correct, and that, as far as practice can be brought in confirmation of it, I have shown that the division of weight on a number of wheels is practically best, both for the horses and for the roads ; it follows that the principles on

which our Turnpike-Acts are founded, as far as they tend to encourage the use of carriages of one description, and to discourage those of another, are entirely erroneous. I conceive that the tolls should be imposed on the *wheels* only, without regard to the number of horses; because upon the principle before mentioned, that action and re-action are equal, the quantity of power actually used or expended, to draw any particular carriage, can only be equal to the resistance of that carriage.

2. If an extra number of horses be applied to a broad-wheel waggon, the owner is liable to be fined. Suppose eight horses to be the limited number: in going up-hill they are perhaps obliged to exert themselves to the utmost, to draw the load after them; but if sixteen horses were used in ascending this hill, still no more power would be applied *to the waggon*; each horse would then exert himself only half as much as in the case of the eight horses; and consequently

the strain of the horses' feet against the ground, at any one point, would be only half so much. But, upon the principle I have before urged respecting the division of power, the injury done to the road from this cause, would not perhaps be one twentieth part so much, as in the case of only eight horses.

3. I consider that an eight-wheel coach, carrying gross weight forty-eight hundred-weight, would run easier to the horses, in a very great degree, than a four-wheel coach of the same weight. I consider also that an eight-wheel waggon, to weigh itself sixteen hundred-weight, carrying thirty-two hundred-weight of goods, might be easily drawn by two ordinary cart-horses, at the usual rate of road waggons; four-wheel waggons, carrying several hundred-weights more than half that weight, being now drawn by one horse—that such a carriage might be driven by a man on the box; and that it would answer all the purposes of the public carriers,

it being several hundred-weight per horse more than they usually draw—that carriages of this description, with springs, might also be used, by the public carriers, with four light horses, at the rate of six miles an hour—that, by the introduction of such carriages, the traveller would be relieved from one of the greatest annoyances he has to encounter, viz. the gothic, broad-wheel waggon. That therefore carriages, bearing on the road at the rate of six hundred-weight per wheel should pass at the lowest rate of toll; and that on all wheels above that weight the tolls should be increased.

4. We need not, then, trouble ourselves about the shape or breadth of wheels. If we get rid of heavy pressure, we gain a great point. Even a drug-mill cannot grind, unless it be heavy. And it happens that, the narrower the wheel, the less is the *twist*; consequently, wheels that are both light and narrow cannot do much mischief.

5. Nevertheless, I mean not to plead for *dishing* wheels, however small they may be, or however lightly they may press on the roads; it being shown before, that upright, cylindrical wheels, whether wide or narrow, with axles perfectly straight, and with cylindrical ends, being the *only* form that has a natural tendency to roll straight forwards, should *always* be used; as they must, under *every circumstance*, be less injurious to the roads, and, in that degree, must cause less labour to the horses than wheels of any other form.

CHAPTER VIII.

1. *Principle on which Tolls ought to be imposed.*
- 2. *How a Table of Tolls ought to be calculated, to meet this principle.*—3. *A Table of Tolls, calculated on this principle.*—4. *Operation of Tolls so calculated. Opinion of JOHN LOUDEN M^cADAM.*—5. *Opinion of the Legislature, in 13th Geo. III. on the injury caused by excessive weights. Sixteen-inch rollers, as now constructed, liable to an additional toll of Forty Pounds.*—6. *Breadth of Wheels no security against the destructive effect of pressure, further shown.*—7. *Probable reasons why Heavy Waggon were formerly encouraged.*—8. *Wheels of light pressure more urgently necessary, where the materials for roads are of a soft and bad quality.*

1. IN suggesting the adoption of a new principle on which to levy tolls on carriages, it is proper that I should explain the reasons for which I venture to suggest it.

A Turnpike-road is proposed to be made ; and, in order to purchase the necessary lands and to procure labour and materials to carry the work into effect, funds must be obtained ; for which purpose, money is bor-

rowed ; and the tolls to be collected are pledged to the lenders, to pay not only the interest, but, by degrees, the principal also. The tolls therefore ought to be levied on every carriage, at such a rate as will repair the damage done by such carriage in travelling over it ; and a further additional sum towards the interest and principal of the borrowed money, and no more. It ought not therefore, in my opinion, to be taken into account, with what the carriage is loaded, that is to say, whether it be loaded with human beings, or with manure, or with any kind of merchandize—whether it be a cart or a gig, a coach or a waggon. The only consideration ought to be, how much money will it require to repair the damage done by such vehicle to the road, together with a reasonable sum for the other purposes. This, as I have before stated, is to be estimated only by the number of the wheels, and the weight with which they respectively press the road ; without any regard whatever to the number of horses drawing such carriage.

It is time that the principle, and also the practice, of favouring one species of commerce at the expense of another, were entirely laid aside. But, to be consistent, if we suffer manure to pass toll-free, in order that the *necessaries of life* may be rendered at a low price, we ought also to grant the same indulgence to live cattle ; to butchers' carts ; to millers' carts and waggons ; to farmers' carts and waggons, carrying corn, potatoes, turnips, carrots, and cabbages ; to the thousands of market-carts, with butter, eggs, veal, pork, poultry, &c. ; to bakers' carts ; to brewers' drays ; to carts and waggons loaded with coals and other fuel ; to carriages loaded with wool or flax, raw and manufactured. And, as houses to live in are also *necessaries of life*, we ought to exempt building-materials of all descriptions, viz. stones, bricks, tiles, lime, sand, and timber.

2. In making out a Table of Tolls, it ought, upon the principle I have laid down, so to be calculated as to encourage, as much

as possible, the greatest division of weight ; so that it should never be the interest of the owner of any carriage to lessen his number of wheels: that is to say, that any given weight should always pay less toll on eight wheels than on six wheels, and less toll on six wheels than on four wheels, and less toll on four wheels than on two wheels.

3. A Table of Tolls, calculated in the following proportions, would effect this object, viz.

	Weight in Cwts.	Increased Toll.			Total Toll.		
For every pair of wheels bearing on the ground with a weight not exceeding	12 ..				.. 0 0 2		
Ditto	14 ..	0 0	0 $\frac{1}{2}$	.. 0 0	2 $\frac{1}{2}$		
Ditto	16 ..	0 0	1	.. 0 0	3 $\frac{1}{2}$		
Ditto	18 ..	0 0	1 $\frac{1}{2}$	.. 0 0	5		
Ditto	20 ..	0 0	2	.. 0 0	7		
Ditto	22 ..	0 0	3	.. 0 0	10		
Ditto	24 ..	0 0	4	.. 0 1	2		
Ditto	26 ..	0 0	5	.. 0 1	7		
Ditto	28 ..	0 0	6	.. 0 2	1		
Ditto	30 ..	0 0	7	.. 0 2	8		
Ditto	32 ..	0 0	8	.. 0 3	4		
Ditto	34 ..	0 0	9	.. 0 4	1		

	Weight in Cwts.	Increased Tolls.			Total Toll.		
For every pair of wheels bearing on the ground with a weight not exceeding	36	..	0	0 10	..	0	4 11
Ditto	38	..	0	0 11	..	0	5 10
Ditto	40	..	0	1 0	..	0	6 10
Ditto	42	..	0	1 1	..	0	7 11
Ditto	44	..	0	1 2	..	0	9 1
Ditto	46	..	0	1 3	..	0	10 4
Ditto	48	..	0	1 4	..	0	11 8
Ditto	50	..	0	1 5	..	0	13 1
Ditto	52	..	0	1 6	..	0	14 7
Ditto	54	..	0	1 7	..	0	16 2
Ditto	56	..	0	1 8	..	0	17 10
Ditto	58	..	0	1 9	..	0	19 7
Ditto	60	..	0	1 10	..	1	1 5
Ditto	62	..	0	1 11	..	1	3 4
Ditto	64	..	0	2 0	..	1	5 4
Ditto	66	..	0	2 1	..	1	7 5
Ditto	68	..	0	2 2	..	1	9 7
Ditto	70	..	0	2 3	..	1	11 10
Ditto	72	..	0	2 4	..	1	14 2
Ditto	74	..	0	2 5	..	1	16 7
Ditto	76	..	0	2 6	..	1	19 1
Ditto	78	..	0	2 7	..	2	1 8
Ditto	80	..	0	2 8	..	2	4 4

Excepting, only, when a load consists of one undivided mass; as a block of stone, one

single piece of iron-work, one piece of timber, or the like; in which case it should be allowed to pass at a certain moderate toll, say at thirty hundred-weight per pair of wheels.

4. The Reader will see that, by the above Table, eight-wheel carriages might pass with very heavy loads, at a very moderate toll: even four tons might pass for 2s. 4d.; while a four-wheel waggon, weighing eight tons, would pay £4 8s. 8d. My friend, John Loudon M^cAdam,* the General Surveyor of the Bristol Turnpike-roads, gives me as his opinion, That the only waggon of this description, which travels between London and Bristol, does more injury to the roads than *all the other carriages* on the road put together, distance for distance. If this opinion be correct, and I have no

* This gentleman is the well-known promoter of the new system of constructing roads, which may be considered as the commencement of a new æra in this important branch of science.

doubt but it is, such toll would be but fairly and moderately imposed.

5. It is plain that in the 13th year of Geo. III. the Legislature were aware of the great injury sustained from excessive weights, by their imposing an additional toll of *twenty shillings per hundred-weight* on all over-weights; but they were not aware that the injury regularly increased, in an increasing ratio, from the lowest weights to the highest; or it does not seem that they knew how to meet the evil. It is on this last-mentioned principle that the above Table of Tolls proceeds.

Besides, as sixteen-inch rollers, contrary to the express letter of the Statute, do not bear with their whole breadth on the road; we have a right to consider eight tons, as carried on nine-inch wheels; we shall then find the overweight to amount to two tons, which, at twenty shillings per hundred-weight, would be *forty pounds!* which is the toll *really intended* by the Legislature

to be imposed ; and which, according to the true intent and meaning, as well as the letter, of the Statute, they are liable to pay.

6. I have said (Chap. IV. § 6) “ The present system of broad wheels I consider a system of mere mockery ;” of which opinion the above-stated fact is an abundant confirmation. In short, if the Law were *literally* obeyed, if wheels were made *perfectly conical*, bearing with their *whole breadth* on the surface of the road, the injury caused to the roads would be ten times greater than it now is from the action of those wheels ; because the dragging backward and forward, or *twist*, would be incomparably greater at the sides of each wheel than at the middle of the rim : whereas, by the present construction, the edges of the rim do not touch the road. (See Chap. II. § 1, *et seq.*) The injury to the roads would also be increased tenfold, from the increased labour of the horses in drawing carriages with wheels so constructed. The fact is, that no

NO WHEEL, generally speaking, whether it be six inches wide, or nine inches wide, or sixteen inches wide, does bear on a flat and even surface *more than about three inches*. Therefore, whether the Law, as it now stands, be strictly enforced, or whether, as at present, it be universally evaded, it must be evident that breadth of rim, in either case, can be no security against the destructive effects of pressure.

7. When we consider the state of the roads throughout England forty or fifty years ago, it is not wonderful that the Legislature should have encouraged the use of heavy broad-wheel waggons by low tolls, and even by a total exemption from tolls; the motive for which evidently was, to break down the large stones which at that time were thrown upon them, as well as to press in the sides of the deep ruts which every where abounded; and that these were the objects, especially the latter, is further evident, by their permitting waggons with nine-inch-wheels, so

adjusted as to roll a surface of sixteen inches on each side, to pass at reduced tolls. But it is difficult to assign any reason why they fixed the maximum-weight of these favoured vehicles at eight tons, imposing on them the enormous fine of twenty shillings per hundred-weight, from eight tons upward.

8. I am aware that it will be objected, by persons resident in districts where the materials for roads are of a soft and bad quality, and where the roads are consequently deep and rutty, that the light wheels I propose would be buried in the ruts ; and that such wheels could therefore never be used. To such I would state what I conceive to be a parallel case. Suppose a Farmer to have a very tender meadow, and he were to turn in heavy oxen ; the consequence would be that these oxen would break the turf at every step, and tread it perhaps six or eight inches deep ; whereas if this meadow were grazed with sheep, the surface of the meadow would be uninjured. Now it should be

remembered that the hoof of the ox as much exceeds that of the sheep, as the weight of the former does that of the latter; but, as in the case of the heavy wheel, it is the intensity of pressure in *one mass* which does the mischief; which is by no means compensated by the breadth of the wheel in one case, nor by the size of the hoof in the other. Nor, if the weight of all the sheep in the meadow were equal to that of all the oxen, would the damage done by the former bear any proportion to that done by the latter: just as I have before stated, the damage done to roads by light wheels would bear no proportion to that done by heavy ones, although in both cases the sum of the weights passing over a road might be equal. Therefore, wherever the materials are bad, and the roads liable to become foundrous, it is exactly in that proportion *more and more important* that wheels of light pressure should be used. As in the case of the meadow, the softer it is, the

lighter should be the tread of the animals with which it is depastured. The fact is that, if wheels of light pressure only were used on such roads, it is not likely that deep ruts would ever be formed.

CHAPTER IX.

1. *Springs, their use explained. How they operate to the ease of the Rider.*—2. RICHARD LOVELL EDGEWORTH'S *Experiment on Springs*.

1. IT is agreed by philosophers that there is in all matter a tendency to continue in the state in which it is, whether of motion or of rest. It requires more power to move a coach or other body from a state of rest than is afterwards required to keep it in motion. Thus we see that horses always exert much more power to *start* a carriage, whether a waggon or a coach, than is afterwards required to continue it in motion; and, when in motion, a considerable effort is frequently necessary to stop it.

When a coach is going with very great speed along a straight road, and suddenly turns a corner, such is its tendency to continue its former course, that coaches have often been overturned from this cause alone.

This principle applies to every variety of motion to which a carriage is liable in travelling. But if a carriage be furnished with springs, although they may be bent, equal to the pressure of the simple weight of the load, it is found, by experience, that the load, rather than alter its course, by suddenly rising over a stone, will bend the springs still farther; whereby, in passing over a stone four inches high, the load may not perhaps rise more than one inch: the springs in this case giving way an extra three inches. And I think I have known the springs of a stage-coach, loaded with about a ton, when passing quickly through a gully or water-course, across a turnpike-road, by first descending suddenly into the gully, and then as suddenly rising out of it, to bend equal to a dead pressure of three tons. And in proportion as it is more easy for the springs to bend than for the weight to vary from its course, in that proportion is the labour of the horses lessened by the use of them.

To the above-mentioned principle it is

that we are indebted for the ease with which we ride on springs. By how much the springs give way to all the little stones and other inequalities of the road, by *so much* do we pass on in an even or horizontal line, more than we otherwise should. For if our roads were perfect mathematical planes, and if wheels were perfect mathematical circles, springs would be useless appendages to any carriage, as they could in no degree add to the ease of the traveller, nor could they lessen the labour of the horses.

2. Richard Lovell Edgeworth details some curious experiments on the subject of springs; the result of which is, that the advantage from the use of springs, when a carriage is going on a *rough* road, at the rate of $3\frac{3}{4}$ miles per hour, is, compared with a carriage without springs, as 12 is to 8. When going at the rate of $5\frac{1}{2}$ miles per hour, the advantage is double, or as 12 is to 6.

From which results, some very important considerations arise. If, as I have above

stated, springs could be of no use, provided the roads were perfect mathematical planes, and provided wheels were as perfect circles; and if it be also true, as I have stated (Chap. I. § 8) that although a wheel may be carried over a stone by the momentum of the carriage; yet that the momentum thereby lost must be restored by extra exertions of the horses; and that this is true is evident, otherwise a carriage, travelling with great speed, would require no more power to draw it on a rough road than on a smooth one; and if it be also true that a carriage without springs, going on a *rough* road at the rate of $5\frac{1}{2}$ miles per hour, requires double the labour that it would require if constructed with springs; and as a very great proportion of all carriages have no springs,—how important is it that our roads should be brought as nearly as possible to the state of mathematical planes! and in order that they may be preserved in this order, that all carriages should be so constructed as to cause the least possible wear and tear upon them.

CHAPTER X.

1. *Suggestions respecting the Tax on Stage-Coaches.*—2. *Private Carriages. Taxed Carts.*

1. I HAVE already hinted that I think it unreasonable and barbarous, that persons who cannot afford to pay the highest price for conveyance by stage-coaches should, because they are poor, be necessarily exposed to the severity of the weather; and that therefore every public carriage ought to be so constructed as to afford shelter for every passenger; but, as the Law now stands, the Proprietors of Stage-Coaches are *compelled*, if they carry more than the inside of the coach will hold, to carry the rest on the *outside*. I therefore think that the license, instead of being granted to carry, say six inside and twelve outside, should be general: that is to say, to carry eighteen passengers; for which the Coach-Master should pay the same tax as he now does.

2. Then, as regards private carriages, coaches, chariots, and one-horse chaises, I take the liberty respectfully to suggest, to those in authority, that the tax ought not to be so imposed as to limit the number of wheels; for two reasons: the first is to be found in the principle I have endeavoured to establish, viz. that the greater the number of wheels, on which any given weight is laid, the better for the road. Now, although this consideration may be trifling, as regards carriages calculated to carry only two or three persons each; yet it is a consideration, and it ought ever to be kept in view. The second reason is the consideration of danger attendant on two-wheel carriages; which is so great, and so obvious, and which is so frequently confirmed by the most frightful accidents, that it is needless to enlarge upon it. I therefore think that as the tax on all these vehicles is imposed, as on articles of luxury, the tax ought to be laid on in proportion to the luxury; which is certainly to be estimated by the number of horses drawing, and not

by the number of wheels on which a carriage stands : in the following manner ; say,

	£	s.	d.
For every Carriage having steel-springs and drawn by only one horse			
Drawn by two or more horses			
For every Carriage constructed without lining or ornament, or steel springs, (but without limitation of number of wheels, or of cost)			

I do think that, on the ground of humanity, in the case of this last-mentioned vehicle, neither wooden springs, nor cushions, nor head, nor apron, ought to be proscribed. It is not likely that many persons, who can afford a better, would submit to so humble a carriage as must necessarily be made under these limitations. And it should be remembered that many females, in slender circumstances, are quite as tender as some who are blessed with affluence, and who consequently can afford an easy and luxurious coach. Having myself occasionally been exposed to the necessity of riding in a taxed cart *without any*

springs, I can say the sensation was dreadful. I therefore think that the use, either of wooden springs, or of cushions, or of shelter from the weather, ought neither to be forbidden to any fellow-creature, nor, which is the same thing, to be put out of his reach by the operation of a severe tax.

CHAPTER XI.

1. *Mechanical Action of Wheels on the Materials of Roads explained.*—2. *Narrow Roads, why so frequently in bad condition. Deep ditches and sudden falls of the ground, close to the sides of roads, productive of ruts.*—3. *Convex Roads never wear well, and why.*—4. *Materials for Roads. Laying on of Materials.*—5. *Whether a thick or thin covering at one time.*—6. *Whether the whole breadth of a road, or only half of it, should be covered at one time.*

ALTHOUGH it was my intention, when I took up my pen, to confine myself solely to the subject of Wheel-Carriages; yet, having had great opportunities of making observations on Roads, I am induced to add a few remarks thereon.

1. It would have been proper, when treating on the form and construction of wheels, to have explained the mechanical operation of wheels on the materials of roads.

The action of wheels on the materials of roads is twofold, viz. *Pressing* and *Grinding*. The *first* is when a wheel passes over any material without any twist, or drag, or slide, as would be the case with wheels made perfectly cylindrical, and standing upright. *Grinding* may, I believe, in every case be defined to be the effect produced on any substance interposed between two bodies, one of which has a sliding motion, yet so firmly confined or pressed between them, that the moving body cannot slide over the interposed substance ; but, in consequence of the pressure, the interposed substance, adhering firmly both to the fixed and to the moving body, is necessarily lacerated or torn asunder, and reduced to atoms. This is the process in Corn-Mills, in Drug-Mills, in Barilla-Mills, and in every other Mill, properly so called.*

* Steel Mills, for grinding pepper, coffee, &c. have very little of this lacerating principle in them. They divide substances by the action of sharp edges one against another, like so many pairs of scissars : they are rather *cutting-machines* than mills.

But, although the ingenious Author I have before cited has very aptly compared broad conical wheels to drug-mills, he was not aware how the destructive effects of them are produced.* I remember frequently, when a boy, to have trodden with one heel on a piece of soft brick, or of dry old mortar, which was firm enough to bear the weight of my body, uninjured ; but, on giving my body a swing round with my other foot, I have instantly reduced it to powder. The action in this case is very obvious: the weight of my body confined the piece of brick firmly to the ground ; my heel was also pressed by the same weight firmly upon the brick : one part of the brick therefore remaining confined to the ground, and the other part being carried round by my heel, the brick of course was torn asunder and reduced to powder. But, were I to try the

* “We do not know with much precision why the twisting or spiral motion here alluded to tends to overcome the attraction of cohesion ; but we know with certainty that the fact is so.”—EDGEWORTH on *Wheel-Carriages*.

same experiment with a piece of limestone, I should find that the friction of my foot would not overcome the attraction of cohesion in this material ; but my body might swing round, my heel sliding upon the stone without injuring it. A similar operation would however produce a like destructive effect on the limestone, provided the moving body were pressed with such a weight that, rather than slide upon it, the attraction of cohesion in the stone would give way. In other words, the harder the substance is, the heavier and more powerful must the mill be to grind it ; and, consequently, the heavier and more powerful is the mill, and the heavier and more powerful is the cart-wheel, the more efficacious in the work of destruction will they necessarily be. This I conceive is a simple elucidation of the difference between *Pressing* and *Grinding*, and this is the difference of the effects on the materials of our roads, produced by the use of upright cylindrical wheels, which act only by *Pressure*, and by the use of conical

wheels, which, by their constant twist, act also by *Grinding*. (See Chap. II. § 1.)

2. I have observed that narrow roads are almost always in bad condition, which is to be accounted for from the circumstance of every carriage being obliged to go in the same ruts; and as each rut is generally only six inches wide, *one foot* of the road only is worn by the wheels instead of the whole breadth of it; which would be the case if the road were of a proper width, and if it were well constructed. If a road be laid out, from twenty to thirty feet wide, so flat as that a carriage may stand nearly upright on every part of it, and if moderate care be taken by the Surveyor to prevent the *first formation* of ruts, such a road will be worn by the wheels nearly alike on every part of it: provided also that the ground on each side, for at least four or five feet, be moderately flat, so as not to excite fear in the drivers of carriages; but if there be deep ditches close to the sides of the road, or if the circumjacent

land fall off very abruptly to the depth of two or three feet, whereby fear of approaching the edges would operate on the minds of the drivers, every driver will *instinctively* avoid the danger on either hand ; and a road so circumstanced will, in spite of any care of the Surveyor, inevitably be worn into ruts in the middle. There is a remarkable instance of this kind in a piece of road on Durdham-Down, near Bristol. This road is a causeway over a piece of soft ground ; and although it is from twenty to twenty-five feet wide, yet, as the ground falls away abruptly on both sides of it, it has been found impossible, for more than twenty years past, to my knowledge, to prevent deep ruts being formed along the middle of it ; notwithstanding the Down itself consists of hard limestone ; and the other roads upon the Down are as fine and even as any roads in England. Were this piece of road widened out on each side, in an easy slope, about five feet, by rubbish of any kind, and by the scrapings of the road itself ; whereby the instinctive operation of

fear of approaching the sides of the present road would be obviated, that piece of road would be found to wear as fairly as the other roads on the same Down.

3. If a road be high and convex in the middle, no care of the Surveyor can prevent the formation of a pair of ruts along the ridge of the road ; this, too, from an instinctive operation of fear : every driver will take this track, as being the *only* part of the road where his carriage can stand *upright* ; and even if it be not so convex as to excite fear, yet the inconvenience of travelling on a sloping road will always produce the same effect.

4. In the use of materials for roads there is seldom much choice ; but Trustees are obliged to use such as the country affords : I have however uniformly observed, in various parts of England, that where limestone is used the roads are the best. And this superiority is not in my opinion owing merely to the hardness of this substance, but also to its

adhesive or cementing property : how, otherwise, are we to account for the firmness and solidity of these roads ? The roads around Bristol that are made of white limestone, I mean that rock-limestone which burns into a white lime, are so firm and compact that they are never affected by the most severe frosts ; which proves that they are quite *impervious to water*. Chalk, being also a limestone, possesses the same cementing quality, and although much softer than the Bristol stone, it may be a good substitute, to mix with harder materials. I was much pleased, the last time I went through Marlborough Forest, at seeing the admirable effect of the union of chalk and flints : the flints being all reduced to a size scarcely exceeding four ounces in weight each, and a quantity of chalk being mixed with them, the road was as smooth, and, as it appeared to me, as hard and compact as the roads on Durdham Down. I am however informed that these roads are affected by frost, because chalk is very absorbent of water : this however I

am persuaded is owing to the chalk being used too abundantly. If used with the broken flints, in the proportion of only one to ten, just enough to form a cementing bed for the flints, I cannot conceive that the quantity of water absorbed would be productive of injury from the effects of frost.

That ground-limestone does possess an adhesive or cementing quality is proved by the fact that the scrapings of limestone-roads are frequently used without any admixture, as mortar, not only for building boundary-walls, but also for building houses, for which purpose it is found to answer tolerably well. It therefore becomes a question, whether the practice of scraping the roads quite clean previous to the laying on of fresh materials, is or is not the best mode of proceeding. It is certain that clean dry stones *cannot* combine until, by the trituration produced by the action of wheels and of horses' shoes passing over them, there is a sufficient quantity of small particles broken off to form a *bed of mortar* for

the remainder ; and that this is the process is clear to me from a fact I have often observed ; which is, that when broken stones are laid on any part of a road in dry weather ; so long as the weather continues dry, these stones will continue loose, however much they may be pulverized by wear during the dry weather ; but immediately after a storm of rain, the whole that has been much worn becomes firm and solid in a day or two. In other words, the powdered stone, which during the dry season was dust, now becomes *mortar*, and the whole is cemented or combined together. Hence I am satisfied that, when fresh stones are laid upon a road, if a quantity, and not a very small quantity, of the road dirt were thrown back and distributed evenly over the surface, they would *immediately become firmly imbedded together* ; that they would last much longer, owing to the trituration of them one against another in their rough and dry state being prevented by their being thus protected from the direct action of

wheels and the shoes of horses : besides which, they would not be so likely to wear into ruts.

This is not however mere theory ; for, having twice served the office of Surveyor of Parochial Highways, I have proved the beneficial effects of this practice, and this too with an ordinary red sand-stone. How far, consistently with my theory, it might be advantageous to lay new materials on unscraped roads, I have not proved.

5. As the wheels of carriages act upon the materials of roads like drug-mills, it may be well to take a lesson from the actual practice of these machines. Having many years ago occasionally worked at a mill of this description, which was used for pulverizing the residuum or caput-mortuum of the Nitrous Acid Manufactories, which is a hard saline substance, I always found that when I overcharged the mill it would not grind, but the salt formed into a mass, and the

runner passed over it, producing but little comparative effect ; but when I threw *small quantities* on the bed of the mill at a time, so that each piece might come in contact both with the bed of the mill and with the runner, the work proceeded with dispatch : each piece then shared the fate of the piece of brick under my destructive foot, and by precisely a similar process. The same effects I have observed in the laying on of materials on the roads. A covering from four to five inches thick forms a bed or mass, which is proof against the severe crush of heavy wheels ; while in the case of a very thin covering, the stones lying bare upon a hard road, and receiving in this unprotected state the stroke of every wheel that passes over them, like the thin covering on my mill-bed, they are quickly reduced to powder, and disappear.

On recurring to my juvenile experiment, it must be evident that, had I tried to grind to powder with the twist of my heel a piece

of soft brick that was firmly imbedded in earth, I should have tried in vain; because in this case I must also have twisted or loosened the body of earth with which it was surrounded; which I could not have done: therefore the only effect I could have produced would have been a slight trituration of its surface. This is also the case with heavy wheels: stones in a thick bed are protected from the immediate destructive *grind*; while stones that are thinly laid on are instantly reduced to powder.

6. I have generally observed that when a piece of road is covered entirely across with new stones, every carriage follows the track of the first, until a pair of ruts be formed; and this can be prevented only by the vigilance of the Surveyor, in causing the ruts to be filled up, by the use of iron rakes; and the labour in drawing heavy carriages over such fresh laid materials is *excessive*, particularly up hills. Whether or not, by the plan I have suggested, of

spreading dirt over the new stones, the tendency of ruts forming would be *entirely* prevented, I am not certain ; but it is certain that the labour of the horses would be very much reduced in passing over them ; and it is also certain that the stones would not be so liable, nor, I believe, in any degree liable to be displaced by the pressure of the wheels and by the straining of the horses.

It was formerly the custom, on some of the Bristol roads, to lay only *one half* of the road at a time. This was, in my opinion, an excellent practice ; because, as every driver of course took the old road, the newly laid road was gradually worn by the wheels on *one side* of every carriage, while the horses travelled on the old ; and as the old grew worse, every carriage would gradually draw further and further upon the new stones, until the whole was imperceptibly rendered firm and compact ; after which, if necessary, a similar process might take place on the other side. By this practice the horses were never obliged to go upon

the new stones unless when two carriages passed each other ; the new stones were very little deranged by the wheels, and the horses' feet ; ruts were never formed ; and the roads were always in good condition. I therefore see no reason why such practice should not generally be adopted.

FINIS.

A P P E N D I X.

Remarks on the Friction of Axles, the Elasticity of the Subsoil, and the Softness of the Surface-matter of Roads, as relating to the Principle of Division of Weight.—On Fat and Oils of different kinds, as applicable to the Axles of Wheels, and to other Machinery.

As soon as the foregoing sheets were out of the press, I had a few copies put into boards, for distribution among my Friends, with a view of obtaining any hints that might be offered me before the work should be laid before the Public; and some of the following remarks have arisen in consequence of suggestions thus produced.

The Reader will have observed that my arguments in favour of the principle of division are founded on calculations of the powers requisite to draw wheels, carrying certain weights, over stones or other palpable

obstructions; which are seldom likely to be opposed to more than one wheel at a time. But it is a fact, which I have proved by many years' practice, that three good ordinary horses can draw a ton more with four wheels, than they can with two wheels, not only upon smooth level roads, but also *up hills*. My own Carter has discovered this, contrary to his own prejudice; and it is his constant declaration that my *two horses*, which are strong, active animals, can draw 65 to 70 hundred-weight gross, with the Waggon, quite as easily as the Cart with 50 hundred-weight, even up the hills; the Waggon having narrow wheels, of the heights before mentioned (Chap.V. § 1), and the Cart having 6-inch wheels, 4 feet 8 inches high, with iron axles, working also in olive-oil.

Another circumstance also I will mention. I have a man in my employment, who lately lived two or three years as groom with a neighbour of mine, who kept a two-wheel one-horse Chaise, and a light Phæton; which latter he also frequently drove with

one horse. This man says he always observed that, when his master had been to town, (five miles distant) with the four-wheel Chaise, the horse returned fresher, even though there were three persons in the Carriage, than when he had drawn the two-wheel Chaise, with his master alone; notwithstanding that the differences of the nett weights of the two carriages must have been at least from two to three hundred-weight. This information was not the result of any question from me; but he mentioned it as a very strange thing, and which he very truly said he “could not make out,” as he had “always thought that two wheels followed lighter after a horse than four.”

Here are facts, connected with the principle of division, which have nothing to do with palpable obstructions; there being no ruts, nor any stones unless recently laid, between Frenchay and Bristol; the whole of this road having been what our country-people call *Mac-Adam'd*. And it is demonstrable that these facts *could not*

exist, so far at least as the road is concerned, if the road were a perfect inflexible mathematical plane, and if the wheels were perfect circles. Nor does it appear to me that the inequality of the surface of a good turnpike-road is sufficient to produce these effects. There must, then, I think, be other causes conspiring to produce them.

At an interview I had with J. L. McADAM, shortly after he had read the preceding pages, and had in very handsome terms expressed his approbation of what I had written on the subject of Carriages, he asked me if I did not think it was likely that axle-friction might increase in a ratio much greater than that of the weight. When we consider the nature of friction, this appears to me an almost self-evident position. Friction is the rubbing of two bodies, one against the other ; and we know that if a cart or a waggon were set to work with dry axles and boxes, the rough or projecting parts of the one would lay hold on the rough parts of the other, and they would thus tear each other to pieces :

great quantities of metallic dust would be produced; and great labour must be exerted on the part of the horses to effect it. But it has been found that if any very soft unctuous matter be placed *between* the metals, in proportion as this destructive contact is thereby prevented, in that proportion is the wear of the metals diminished. This is remarkably the case in my own Waggon. Although it has been in use about twelve years, I could not discover, the last time I examined the axles and boxes, that *any* wear whatever had taken place, whether in the iron of the one or in the brass of the other. Now it is certain that olive-oil will prevent destructive friction, with very considerable weights acting on the sliding-bodies; but, whenever the weight becomes so excessive upon an axle as that the axle shall drive the oil before it, or press the oil from under it, so that the metals come into absolute contact, the friction must become prodigious; and this increase of friction must be produced in proportion as the weight has this tendency,

of displacing the oil and of forcing the metals into contact ; and it is therefore clear to me that a double weight might thus produce a tenfold friction.

Another circumstance has also attracted my notice, since the body of this work was printed ; which is, the Shaking of the Roads. It was first suggested to me by ROBERT ANSTICE, of Bridgewater, who is a gentleman of great ingenuity, and of great accuracy in observation. The same fact I see recorded by the Quarterly Reviewers, in their notice of several Works on the subject of Roads, (*May 1820,*) with this very important fact accompanying it, viz. that the materials on the road between Cross and Bridgewater, when compared with similar materials on roads lying upon a hard rock, last in the proportion of seven to five. The fact is so well attested as to leave no doubt with me of its perfect accuracy. But how or why do these stones last longer on an elastic bed than on a hard rock ? Precisely for the same cause that a stone placed upon a wool-

pack would bear a greater pressure before it would be broken, than it would if placed on an anvil. Now the road in question is not over a soft spongy bog, although this level is well known to have been formerly *sea*: it is a country formed entirely by the deposit of slime from the Bristol Channel; and it is now one of the richest grazing-districts in England, with a sound clay-bottom; the meadows being every where firm enough to carry oxen of the heaviest weights.

The knowledge of this shaking has led me to consider the nature of the foundations of roads in general. In this country, the proportion of road that lies upon bare rock is very small; all the rest may, in one general term, be said to lie upon *earth*. Now earth of every description is absorbent of water. It is so ordered by the Great Author of Nature, for the purposes of nature; to support not only vegetable life, but also the myriads of animated beings that exist under the surface of the earth. Water circulates and

percolates through every pore ; and gases also abound, to a very considerable depth ; consequently the whole surface of the earth may be considered, in some degree, as an *elastic body*. It is not, therefore, only in the neighbourhood of Bridgewater that the roads are elastic, and that water would be seen to tremble in the ditches at their sides, if ditches full of water existed. We hear the windows of houses, and the plates and glasses on the shelves, rattle when a carriage passes by, not near Bridgewater only, but in London and Bristol, and every where else. Consequently I consider that *all our roads*, excepting only those that lie in immediate contact with a hard solid rock, are to a certain extent elastic. But even the surface-matter of the road itself is, generally, taking England throughout, more or less pervious to water, and is therefore more or less elastic or yielding. In proportion, therefore, as this elasticity, or softness, or compressibility, or by whatever term it may be designated, exists either in the subsoil or in the road-matter,

or in both, in that proportion will weights sink in passing over such roads. But I have endeavoured to show, in the case of Oxen and Sheep in a soft meadow (Ch. viii. § 8), that the effect of weight increases in a much greater ratio than the weight itself increases. Thus, suppose a Sheep to weigh exactly one-tenth part of an Ox ; the foot of the Ox would tread the turf five inches deep, while the foot of the Sheep would not make an impression exceeding an eighth of an inch in depth, or a fortieth part of the depth of that of the Ox ; but as the hoof of the Ox exceeds that of the Sheep in superficial measure about ten-fold, the Sheep by its tread would not displace more than one part in four hundred of the quantity of earth which the Ox would.

If, then, it be granted that all *earth* abounds with both air and water, it follows that such earth is elastic or compressible. But a very great proportion of all the roads in England have a depth of this earth or compressible matter under them. And the

surface-matter of all gravel-roads, being also absorbent both of air and water, such roads must necessarily be *still more* compressible or yielding.* Consequently all roads, excepting only those that lie in immediate contact with a hard rock, must yield, or bend, upon the principle of elasticity, or must sink in consequence of the looseness of the road-matter; and in many instances both these causes must combine to produce a resistance to every wheel that passes over them: which will be in proportion to the compressing power of such wheel. But it is shown that the compressing powers of weights, acting upon earth, increase in a ratio manifold greater than the weights themselves increase.

In enumerating the various objects of resistance to Wheels (Ch. I. § 3), I have stated the pressure of wheels into the surface-matter

* May not this account for the fact stated before the Committee of the House of Commons, by the Proprietors of Stage-Coaches, that their horses do not last more than about half as long near London as they do in more remote districts?

of roads as a cause of “prodigious expenditure of the strength of horses ;” but I was not then aware of what is evidently the fact, that this pressure or sinking is not simply proportioned to the respective weights, but that it increases, as already mentioned, in a ratio manifold greater than that of the weights themselves.

These considerations, with the preceding arguments, afford an explanation, satisfactory at least to myself, of all the circumstances attendant on the Division of Weight. They explain the cause why horses can draw seven or eight hundred-weight each, even upon a smooth road, and up a steep hill, in a Waggon, more than they can in a Cart ; they explain the cause why my neighbour's horse always came home fresher from Bristol, with his master's Phæton, than with the Gig, even though he had several hundred-weight more behind him ; and they tend to establish the assertion of the man who drove the eight-wheel Coach between Bath and Bristol, that *it followed very light after the*

horses ; which was only saying, in other words, that they drew it with great ease.

In whatever point of view, therefore, we look at the principle of Division, whether it be as regards the drawing weights over stones and other palpable obstructions, or over the little inequalities of the roads ; or as regards the elasticity of the roads, and the sinking of the wheels into the surface-matter of them ; or as it regards the friction of axles ; or as it affects the duration of the roads themselves ;—it appears to me to be alike important.

Grease, or fat oils, of any description, will prevent friction ; but some are found to answer this purpose much better than others. Hard fat is objectionable, on two grounds : first, on account of its toughness, or the difficulty with which its parts are separated from each other, which necessarily requires labour to effect ; secondly, its want of fluidity ; whereby the working-part of any machine may often be quite bare, while the fat is deposited in considerable thickness where

it is of no use. Fish-oils are frequently used about machinery, because they are bought at a low price. Now, all these oils contain a portion of gelatinous matter ; which may be proved by treating them in a phial with a decoction of oak-bark or of nut-galls. When shaken together, a chemical union is formed between the tannin, or tanning principle of the oak, and the gelatine ; and, if the phial be set by to stand for a few days, the purified oil will rise to the top ; the aqueous fluid, or tan-liquor, will separate at the bottom, and the *leathery* matter, formed by the union of the tannin and gelatine, will be seen in the middle. This is the case with all the fish-oils, even with pure spermaceti-oil, although not in the degree as with cod and common whale oils. I have found some samples of the latter sorts, when shaken with about an equal quantity of strong bark-liquor, to form into a thick mass like a custard ; and, after it has stood a month, I have not discovered any separation to take place : consequently a *very large* portion of

such oils must be jelly. Now it is found that, when fish-oils are used about machinery, or about the axles of wheels, the oil evaporates, or passes off; and the gelatinous matter remains, adhering to the machinery, like gum: therefore fish-oils should never be used about machinery of any kind. This deposit of jelly is also observed on harness on which coarse fish-oils are used; but I have not observed it after using *pure* spermaceti-oil. This *seems* to be entirely absorbed by the leather, without leaving any deposit of gelatine or gummy matter on the surface of it; the leather handling smooth and clean, and remarkably mellow with its use. *Pure* olive-oil possesses none of the properties that render solid fat or fish-oils objectionable for machinery; and it is the only substance that I know of which is proper to be applied either to cart-wheels or to machinery of any kind; for the former of which purposes I think the best method of applying it is with a small painting-brush; and there is nothing better to keep it in, for use, than a common

tin pint-porringer, with a cover to keep out the dust; in which cover should be a notch, to admit the handle of the brush. Three or four ounces of oil, given to the carter at once, will thus last a long time; as, by the use of the brush, he need not waste a drop of it.

I should not suppose that the quantity of gelatine in sperm-oil would render it objectionable for carriage-wheels; but I have found it so thin that the boxes would not retain it, and the wheels would not go twenty miles without complaining. I have however found that sperm-oil proves *gummy* about the works of a steam-engine. I lately gave a phial of very fine sperm-oil, purified by the before-mentioned process, to a watchmaker, thinking it might prove excellent for the pivots of watches; but it was *too thin* or too volatile even for that use. He said it was *soon gone*; but the watches worked remarkably well with it.

T. J. Manchee, Printer, Bristol.

